MACHINIST'S MATE 3

NAVY TRAINING COURSES

NAVPERS 10522

MACHINIST'S MATE 3

Prepared by

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES

NavPers 10522

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ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
SERVICE	4 mos. service— or completion of recruit training.	6 mos. as E–2 or 8 mos. total service.	6 mos. as E–3 or 14 mos. total service.	12 mos. as E–4.	12 mos. as E–5; total service at least 36 mos.	36 mos. as E–6.
SCHOOL	Recruit Training.		Class A for PR3, PRS3.		Class B for MN1.	Class B for AGCA, MNCA, MUCA.
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.			
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E–3 and all PO advancements.				
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.			
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.			
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E–3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.				
AUTHORIZATION	Commanding Officer		U. S. Naval Examining Center			BuPers
	TARS are advanced to fill vacancies and must be approved by district commandants or CNARESTRA.					

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
	FOR THESE DRILLS PER YEAR						
TOTAL TIME IN GRADE	24 OR 48 12 NON-DRILLING	9 mos. 9 mos. 12 mos.	9 mos. 15 mos. 24 mos.	15 mos. 21 mos. 24 mos.	18 mos. 24 mos. 36 mos.	24 mos. 36 mos. 48 mos.	36 mos. 42 mos. 48 mos.
DRILLS ATTENDED IN GRADE#	48 24 12	27 16 8	27 16 13	45 27 18	54 32 20	72 42 32	108 64 38
TOTAL TRAINING DUTY IN GRADE#	24 OR 48 12 NON-DRILLING	14 days 14 days None	14 days 14 days None	14 days 14 days 14 days	14 days 28 days 14 days	28 days 42 days 28 days	42 days 42 days 28 days
PERFORMANCE TESTS				Specific ratings must complete applicable performance tests before taking examination.			
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 1316, must be completed for all advancements.					
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.					
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.					
AUTHORIZATION		District commandant or CNARESTRA					BuPers

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

#Active duty periods may be substituted for drills and training duty.

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

READING LIST

NAVY TRAINING COURSES

Basic Hand Tool Skills, NavPers 10085 (Chapters 1–6, 10)
Blueprint Reading and Sketching, NavPers 10077-A (Metal working skills only)

OTHER NAVY PUBLICATIONS

BuShips Manual, Chapter 4, Section I; 6, Sections II, III, IV; 58, Section I; 59, Sections II, III

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer.* A partial list of those courses applicable to the Machinist's Mate rating follows:

Correspondence

Number	Title
CB 856	*Shop Mathematics I*
CB 857	*Shop Mathematics II*
CC 936	*Refrigeration*
	Self-Teaching
MB 856	*Shop Mathematics I*
MB 857	*Shop Mathematics II*
MC 936	*Refrigeration*

* "Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified in the active duty orders."

PREFACE

This training course is written for men of the Navy and of the Naval Reserve who are studying for advancement to the rate of Machinist's Mate 3. Combined with the necessary practical experience and a thorough study of the related basic Navy training courses, the information in this course will prepare the reader for advancement-in-rating examinations.

The qualifications for Machinist's Mate 3 are listed in Appendix II at the end of this training course. Since examinations for advancement are based upon these qualifications, frequent reference to them will prove helpful.

This training course deals principally with the operation of shipboard engineroom equipment; however, other machinery for which engineroom personnel are responsible is also discussed.

The training course is keyed to the practical needs of a Machinist's Mate watch stander. The course opens with a discussion of the duties of a Machinist's Mate 3, and the qualifications for advancement in rating. It continues with chapters devoted to engineering piping systems, main and auxiliary turbines, reduction gears, and bearings and shafting. The course then takes up the operation and maintenance of auxiliary machinery, including distilling plants, air compressors, refrigeration units, industrial gas equipment, and hydraulic equipment.

As one of the NAVY TRAINING COURSES, this training manual was prepared by the U. S. Navy Training Publications Center for the Bureau of Naval Personnel. Technical assistance was furnished by the U. S. Naval School, Machinist's Mates, Class A, U. S. Naval Training Center, Great Lakes, and the Bureau of Ships.

MACHINIST'S MATE 3

CHAPTER 1

PREPARING FOR ADVANCEMENT

As a striker for Machinist's Mate 3, you will learn all about WHAT the Machinist's Mate does, WHERE he does it, HOW he does it, WHY he does it, and the operating principles of the various engineering machinery and systems with which you will work.

DUTIES OF THE MACHINIST'S MATE

Machinist's Mates operate and maintain the steam propulsion engines (including the turbines, reduction gears, condensers, air ejectors, etc.), and such miscellaneous auxiliary equipment in the engineering spaces as pumps, air compressors, generators, evaporators, valves, oil purifiers, oil and water heaters, governors, propeller shafts, etc. The Machinist's Mates maintain and make minor repairs to various types of hydraulic and steam machinery outside the ship's engineering spaces, such as the steering engine, anchor windlass, elevators, cranes, and winches. They operate, maintain, and repair the ship's refrigeration and air conditioning equipment. In some cases Machinist's Mates are assigned duties involving the production and handling of such industrial gases as oxygen, acetylene, carbon dioxide, helium, nitrogen, and hydrogen.

GENERAL AND EMERGENCY SERVICE RATINGS

The Machinist's Mate rating has a dual breakdown in classification—the general service and emergency service ratings.

The GENERAL SERVICE RATING, Machinist's Mate, is classified as MM. This is the rating which applies in normal, peacetime operations. The training mission of the peacetime Navy is to produce broadly qualified, versatile personnel who, in time of emergency, can be advanced to positions of greater responsibility and authority.

The rating structure must be flexible in order to permit expansion, in time of national emergency, from broad, general service areas to narrower emergency service areas within the same rating. To provide for this expansion, EMERGENCY SERVICE RATINGS and EXCLUSIVE EMERGENCY SERVICE RATINGS were established. These latter two areas are not used by the regular Navy in peacetime, but may be activated in time of emergency.

The Machinist's Mate emergency service ratings are MML (General Machinist's Mate), MMR (Refrigeration Mechanics), and MMG (Gas Generating Mechanics). These ratings represent the three specialized subdivisions into which all personnel of the MM general service rating are channeled in time of national emergency.

Following a national emergency and upon returning to a peacetime organization, regular Navy personnel in emergency service ratings will be required to qualify for a general service rating. Members of the Naval Reserve, however, will be carried in their proper emergency service ratings.

THE MACHINIST'S MATE AS A PETTY OFFICER

In striking for the Machinist's Mate rating, you are also reaching for the rate of a petty officer 3. Therefore, it is not enough that you meet the technical qualifications required for the MM3. You must also be considered qualified (by both observation and examination) for the

military responsibilities of a PO. It is well for you to remember that you will be required to be A MILITARY LEADER as well as a technical specialist.

Petty Officer Qualifications

To meet the military requirements for advancement to petty officer 3rd class, you must pass certain practical factor qualification tests and a written examination on military subjects including conduct, regulations, and the administrative duties of petty officers. Information covering these requirements is contained in *General Training Course For Petty Officers,* NavPers 10055. It is very important that you study *General Training Course For Petty Officers* in conjunction with your study of this training course in your preparation for advancement to MM3.

Briefly, the PETTY OFFICER QUALIFICATIONS with which you must be concerned pertain to fundamentals of naval leadership, general duties of petty officers and of military police patrols, duties as petty officer of the watch, identification of rank or grade of personnel in other branches of the Armed Services, naval and ship organization, regulations concerning classified information, military honors and salutes, elementary mathematics applicable to machinery operation and maintenance, use of technical diagrams and blueprints, construction characteristics of naval ships, prevention and control of ship's damage, fire fighting, protective and remedial measures to be taken with regard to atomic, biological, and chemical warfare, special military police duties, physical drills, care and use of small arms, infantry drills, landing force operations, and naval publications of value to you.

Of all the qualifications required of you (in addition to your specialized technical knowledge and proficiency regarding naval machinery), that of MILITARY LEADERSHIP ABILITY is by far the most important. But do not forget that you cannot be a good military leader as a

Machinist's Mate unless you also have a good working knowledge of your naval machinery.

Know Your Job Well

The way for you to DO well in your job as a Machinist's Mate is to KNOW your job well. This means having a mastery of all the mechanical skills involved. It also means having a clear understanding of the fundamentals of physics and engineering underlying the operations of your machinery. It means knowing the individual characteristics of each piece of machinery installed on your ship —where it is, how it is constructed, how it operates, how it differs from other machinery, how it fits into the ship's piping systems and engineering plant, and how it and its related machinery and systems are controlled. It means, too, knowing the history of its operation and maintenance, what care it should be given, what precautions should be taken in its use, what abnormal actions it can develop, and what the symptoms, causes, and remedies of these abnormalities are.

It means knowing the organization of your ship's engineering department, knowing your part in the over-all plan of operation, and knowing and utilizing the superior skills and knowledges of your engineering shipmates. Remember that the man who really knows his job is the man who is recognized for advancement. Knowing the job a couple of steps ahead is also to your advantage; so KNOW HOW and KNOW WHY.

Experience Plus Book Knowledge

The best training for your job as a Machinist's Mate is a combination of your own ACTUAL EXPERIENCE with BOOK KNOWLEDGE and the EXPERIENCE OF OTHERS. Be sure that you give adequate time to the study of this training course for MM3, which has been prepared to guide you in your training for this rate.

Learn all you can by actual work with the ship's machinery. Ask Machinist's Mates with experience to help

you on matters that puzzle you. Study the records of your ship's engineering machinery, and the related manufacturers' pamphlets, instruction books, and diagrams. Consult the *Bureau of Ships Manual* and other books on naval machinery and engineering that may be on file in your ship's log room. Know the qualifications for advancement in rating, see Appendix II,—and meet them. Review the contents of *Fireman,* NavPers 10520–A. And be sure that you know what will be expected of you.

PUBLICATIONS YOU SHOULD KNOW

As a Machinist's Mate, you should be familiar with a number of publications. Some of these pertain specifically to the technical duties of your rate and rating; others pertain to your military duties as a petty officer. Some of the publications are issued by the Department of the Navy and its bureaus; some by manufacturers and commercial publishers; some by the fleet and force commanders; and some by your own ship or engineering department.

Bureau of Ships Manual

Certain chapters of the *Bureau of Ships Manual* will be of particular interest to you as a PO and MM. The engineering data and instructions contained in this manual cover all the types of machinery and equipment installations of your ship or station. The information given is in accordance with the most modern and best engineering practice for the operation and maintenance of naval machinery.

Brief descriptions of various types of machinery units or plants, and examples of certain subtypes in the same class supplement these engineering instructions. You will find descriptions of various parts of the machinery; instructions for starting, operating, and securing; limitations and safety precautions to be observed in conjunction with operation; lists of troubles that may occur and what

to do about them; maintenance routines; tests and clearances; instructions for overhauling machinery, and other related information. You will also find material pertaining to the construction and layout of the ship itself. In short, the more familiar you are with the *Bureau of Ships Manual,* the better informed you will be concerning the ship's machinery.

Instruction Books and Diagrams

For more detailed and specific technical information, however, you must go further than the *Bureau of Ships Manual.* You must consult the numerous manufacturers' and NavShips INSTRUCTION BOOKS and diagrams which apply specifically to the individual machinery installations aboard your ship. This material is filed in the ship's log room. You will find that there is a manufacturer's instruction pamphlet for practically every piece of machinery and equipment aboard. These pamphlets describe in detail the construction of the machinery; instructions on how to operate and adjust the machinery, how to maintain it efficiently, and how to disassemble repair and reassemble the machinery.

The NAVSHIPS INSTRUCTION BOOKS, prepared by BuShips in conjunction with the manufacturers, give detailed instructions on the operation and maintenance of the various types of engineering machinery, plants, and piping systems of your ship. This information, plus the WORKING PLANS used by the building yard, copies of which are filed in the log room, are the sources of information for the ENGINEERING CASUALTY CONTROL BOOK, which contains the final and authoritative set of directions to you—the man on watch in the machinery plant.

A MECHANICAL DRAWING can convey more technical information to a person trained to read it than many pages of descriptive matter or photographs. Before any piece of machinery is constructed, an accurate mechanical drawing of the machine is made. The machinist, when

constructing the equipment, must interpret the designer's specifications and dimensions on the drawing.

Duplicate BLUEPRINT COPIES of these manufacturers' drawings for each piece of equipment aboard your ship are stored in the ship's log room. They are available for reference, and you should use them freely if you want to understand your propulsion and auxiliary machinery. To understand and use these machinery prints, as well as the piping system diagrams and the prints of the machinery arrangements and layout on your ship, you must thoroughly understand working drawings, orthographic projections, the scales of drawings, sectional views, breaks in drawings, types of lines used, and the abbreviations employed. The basic Navy Training Course, *Blueprint Reading and Sketching,* NavPers 10077–A, will aid you in this.

Personal Safety

In the 7 years from 1946 through 1952 inclusive, 76 military personnel of the United States Navy were killed by electric shock. Of this number, 22 were involved in shipboard fatalities—and one of these resulted from a man touching a portable submersible bilge pump.

Shortly before the incident the pump had been repaired, tested without accident, and found to run. But no test had been made to check insulation resistance to ground and correctness of ground connection. After the accident it was found that phase A of the power supply was connected to the ground terminal on the motor terminal block, and that the grounding conductor was connected to terminal A of the motor. The motor ran when it was tested, but it was nonetheless connected improperly and was deadly.

Another case involved a portable drill. The man using the drill received two nonfatal shocks before the fatal shock; one in the morning when his hands were bare, and another in the afternoon when wearing a pair of greasy gloves. After the second shock the operator wore a

pair of clean gloves for a time, but ultimately discarded these and was working with bare hands when he picked up the drill late in the afternoon and was fatally shocked. Mistake was piled upon mistake to lead to a fatal conclusion. The first mistake was made by the man who should have tested but did not test the drill for insulation resistance and soundness of ground connection before the drill was put into use. The second mistake was made by the user of the drill, when, after receiving a nonfatal shock while working with bare hands, he failed to have the drill repaired and merely put on greasy gloves. The third mistake was made when a nonfatal shock was received while wearing greasy gloves. It was still not too late to fix the drill, but all that seems to have been done was to shift from greasy to clean gloves. And then, finally, one more mistake. The clean gloves were discarded, probably while the drill was not being used; the drill was picked up with bare hands, and a man was killed in an accident which would have been avoided had proper attention been paid to the warnings which preceded it.

Even though the care and maintenance of electrical equipment is the responsibility of an EM, you as an MM should be familiar with the general precautions to be observed when you are working around electrical equipment. Safety precautions must always be observed by persons working around electrical circuits and equipment, in order that injury caused by contact with an electrically charged unit may be avoided.

Electric shock from contact with an energized circuit can cause serious injury. Even low-voltage circuits can cause death upon contact, especially when current passes through the chest. Shipboard conditions are particularly conducive to severe shocks because (1) the body is likely to be in contact with the ship's metal structure, and (2) the body resistance to electricity may be low because of perspiration or damp clothing. Extra care is therefore needed when you are working in the vicinity of electric circuits on board ship.

Care should be exercised to prevent short circuits. A short circuit may be caused by accidentally placing or dropping a metal tool, a ruler, a flashlight case, or some other conducting article across an energized line. The arc, and the fire which may result, from even relatively low-voltage circuits may cause extensive damage to equipment and serious injury to personnel.

Safety precautions are posted in the vicinity of electrical equipment. If these simple precautions are observed, injury or accident will seldom occur when you are working around electrical equipment. When working in the vicinity of electrical equipment, keep in mind that electricity strikes without warning; that hurrying reduces caution and invites accidents; that taking chances is an invitation to trouble; and that every electrical circuit is a potential source of danger.

Even when safety precautions are carefully observed, accidents may occur. You should be familiar therefore, with the procedures to be followed when rescue from electrical contact is necessary, and when injuries from electricity have been received. Rescuing a person who is in contact with an electrically charged object is likely to be a difficult and dangerous job. Extreme caution must be used; otherwise, you may be electrocuted yourself. You must not touch the victim's body, the charged object, or any other object which may be conducting electricity.

When rescuing a person from an electric contact you should, first of all, look for the switch. When you find the switch, shut off the current immediately. Do not spend much time hunting for the switch, however; every second counts. If you cannot find the switch rapidly, try to move the victim's body off the electrically charged object. Use anything dry and nonconducting, such as a stick, a pole, an oar, or a board. It may be possible to use dry rope or dry clothing to pull the wire away from the victim. You can also break the contact by cutting the wire with a wooden-handled axe, but this is extremely dangerous; the cut ends of the wire are likely to curl and lash back at you

before you have time to get out of the way. When you are trying to break an electrical contact, always stand on some nonconducting material, such as a dry board, dry clothing, or a rubber mat.

The passage of electric current over the skin or through the body may result in asphyxiation, burns, or shock. Asphyxiation is the primary danger and is likely to occur when the skin is wet. Burns are most likely to occur when the skin is dry. Shock (a serious disturbance of the blood flow) accompanies or follows asphyxiation and burns.

When someone receives injuries from electricity, you should proceed as follows:

1. Deenergize the circuit or release the victim from contact. Avoid unnecessary danger to yourse'f by observing all appropriate precautions.
2. If the victim is not breathing, treat for asphyxiation. Begin artificial respiration immediately. Keep the victim quiet after normal breathing is reestablished. As the victim is recovering, he may go through a period of frenzied violence.
3. Treat the victim for shock. Keep him lying down, with his head slightly lower than his feet. Keep the victim warm, but do not overheat him. (Note: Any person who has suffered an interruption of breathing should not be given morphine.) Have someone notify the Medical Department to send a doctor to the scene of the accident.
4. Treat the victim for burns, if necessary. For information on the first-aid treatment of burns see *Standard First Aid Training Course,* NavPers 10081. That reference also gives information on the methods of artificial respiration, and additional information on factors related to injuries from electricity.

In addition, precautions should be taken to prevent personal injury resulting from heat exhaustion and from im-

properly lifting heavy objects. For further discussion in these two areas refer to *Standard First Aid Training Course,* NavPers 10081 and *United States Navy Safety Precautions,* OpNav 34P1.

Navy Training Courses

Other Navy training courses, besides this course for MM3, are essential for your understanding of the Machinist's Mate's job. The importance of *Fireman,* NavPers 10520–A, and *Blueprint Reading and Sketching,* NavPers 10077–A, has already been stressed. Other Navy training courses of importance to you include *Basic Hand Tool Skills,* NavPers 10085, *Mathematics,* Vol. 1, NavPers 10069–A, *Mathematics,* Vol. 2, NavPers 10070–A; *Basic Machines,* NavPers 10624; and *Basic Electricity,* NavPers 10086. You will need these courses for the proper study of the requirements of your rating and rate.

A KNOWLEDGE OF MATHEMATICS, for example, might be compared to a kit of tools carried by a workman. The master mechanic can use more tools than the apprentice, and is thereby enabled to do more and better work. With a good working knowledge of basic mathematics, you will advance more readily than you could without it. All Machinist's Mates need to be able to handle addition, subtraction, multiplication, simple fractions, and decimals.

SUGGESTIONS TO HELP YOUR STUDY

Although every individual has his own methods of studying and learning new subject matter and skills, a few general suggestions may help you to utilize your time to greater advantage. The following suggestions are listed for that purpose:

1. Ask for work assignments that will help you prepare for the examination for the next rate.
2. Ask for the hard jobs—working on them is the best way to learn.

3. If you fail to understand something the first time you read it or try it, don't be discouraged. Ask about it and keep asking till you get the information you need.
4. Try to master one system or one piece of equipment at a time.
5. Benefit by the experience of others. Associate with Machinist's Mates who have demonstrated a thorough and accurate understanding of the ship's machinery and engineering systems; ask them questions; ask them to demonstrate or sketch various points for you.
6. Always try to figure out why the operating instructions tell you to do things in a certain order or manner.
7. Study this course as a guide book, but do not regard it as a full treatment of the machinery, the principles, and the procedures with which you are concerned.
8. Get acquainted with this whole book before concentrating on a chapter or a section; distinguish between less important and more important details in the text; approach the text with DEFINITE QUESTIONS IN YOUR MIND regarding a particular subject, and do not be satisfied until you have found the answers to your questions.
9. After studying a particular chapter, TURN TO THE QUESTIONS at the end of the chapter and write down the answers on a sheet of paper. Try to answer the questions speedily. (Answers are short in most cases.)
10. Be guided in your study by the qualifications for advancement to the rate of Machinist's Mate 3.

QUIZ

1. What three things combine to give you the best training for your job as a Machinist's Mate?
2. Of what value is it to you to know a little more about your job than is required?
3. In time of national emergency, what emergency service rating would you have if your principal duties dealt with refrigeration and air conditioning?
4. Does the Machinist's Mate have any responsibility of greater importance than that of being a naval machinery specialist? If so, what?
5. What technical naval bureau manual is of greatest reference value to you as a Machinist's Mate?
6. What basic Navy training courses should you be familiar with before studying this course?
7. Where on your ship will you generally find diagrams and blueprints of the engineering machinery and systems?

CHAPTER 2

ENGINEERING PIPING SYSTEMS

In this chapter you will be given a perspective of the operation of turbine-driven propulsion plants and the associated auxiliary machinery and piping systems, as well as general descriptions of the physical arrangement of propulsion machinery in one of our newer ships. There are also included brief discussions of piping systems and machinery units not directly associated with the propulsion plant but which none the less serve to perform important functions in a naval vessel.

The principal systems and plants include the main propulsion plant, the various steam piping systems, the steam drain collecting system, the fresh water system, the feed water system, the salt water system, the lube oil system, the refrigeration system, the air-conditioning system, the compressed air system, and the steering system. Some of these systems are discussed in this chapter; others are discussed in detail in succeeding chapters.

This text does not attempt to set down detailed descriptions of the several piping systems—only the general functions. Each ship has a set of working plans, an engineering operation and casualty control manual, a damage control book, and an instruction book pertaining to the ship's engineering piping systems. You should study the diagrams and descriptions in these four sources of information and then trace the various piping systems throughout the ship. Be sure you know where all the

important valves are, and what types of valves they are. This is essential for every Machinist's Mate.

With a general, over-all picture of the ship's engineering plant and systems clearly in your mind, you will be ready to concentrate upon the construction, operation, and maintenance of the various types of machinery that are component units of the systems.

ENGINEERING SYMBOLS

To facilitate your remembering the details of the engineering systems on your ship (including locations of the component machinery, valves, and gages), you should sketch several diagrams of the various piping circuits.

To make it easier to show piping systems on paper, symbols are used to represent the valves and other pieces of equipment. Figure 2–1 shows the symbols generally used in engineering plans and diagrams. Slight differences may exist on some drawings, but in general the symbols will appear as illustrated. You should be familiar with these symbols. They will enable you to understand the plans and diagrams you will study, and to draw your own rough sketches of the systems.

Remember that whatever is said in this chapter about any particular system is general and that each ship is different, even sister ships. Therefore, to actually know your own ship's installation you must check the details for yourself.

POWER FOR SHIP'S MACHINERY

Most naval vessels, with the exception of most submarines, some auxiliaries, and some destroyer escorts, are steam-driven. Steam serves the essential purpose of carrying energy to the engines. The fuel burned in the boiler furnace is the SOURCE of heat energy; the steam generated in the boilers is the MEDIUM by which heat energy is carried to the turbines, where it is converted into mechanical energy. Mechanical energy propels the

LEGEND OF SYMBOLS FOR PIPING DIAGRAMS

SYMBOL	DESCRIPTION
	GLOBE STOP VALVE
	ANGLE STOP VALVE
	ANGLE STOP CHECK VALVE
	ANGLE CHECK VALVE
	GATE VALVE
	SWING CHECK VALVE
	STOP CHECK VALVE
	HOSE GATE VALVE
	HOSE GLOBE VALVE
	HOSE ANGLE VALVE
	RELIEF VALVE
	SAFETY VALVE
	REDUCING REGULATING BACK PRESSURE GOVERNOR OR THERMOSTATIC INCREASED ACTUATING PRESSURE OR TEMP. CLOSE VALVE
	SAME AS ABOVE BUT INCREASED ACTUATING PRESSURE OR TEMPERATURE OPENS VALVE
	SOLENOID VALVE
	NEEDLE VALVE
	WT. LOAD PRESSURE REGULATING VALVE
	MANIFOLD STOP VALVES
	MANIFOLD STOP CHECK VALVES
	DOUBLE MANIFOLD STOP VALVES
	QUICK CLOSING GATE VALVE
	QUICK CLOSING GLOBE VALVE
	THREE WAY COCK
	SPECTACLE FLANGE
	ORIFICE PLATE
	OPEN FUNNEL
	VALVE WITH OPERATING ROD ABOVE BULKHEAD DECK

SYMBOL	DESCRIPTION
	SUCTION SEA CHEST
	OVERBOARD DISCHARGE
	THERMOMETER
	PRESSURE GAGE
	PIPE TURNING DOWN OR AWAY
	AIR OPERATED— REDUCING, REGULATING OR BACK PRESSURE INCREASED ACTUATING PRESS. CLOSE VALVE
	SAME AS ABOVE BUT INCREASED ACTUATING PRESS. OPENS VALVE
	LIFT CHECK VALVE
	SEDIMENT CHAMBER
	TRAP
	METER
	SALINITY CELL
	FILTER
	MICROMETER VALVE
	STOP-CHECK-LEFT-VALVE
	VENTURI
	DIFFERENTIAL GAGE
	COMPOUND VALVE
	EXPANSION JOINT
	SEPARATOR
	SIGHT FLOW GLASS
	MACOMB STRAINER
	DUPLEX STRAINER
	MAGNETIC DUPLEX STRAINER
	STRAINER
	FLOAT VALVE
	STOP CHECK VALVE WITH OPERATING ROD ABOVE BULKHEAD DECK

Figure 2-1.—Symbols used in engineering plans and diagrams.

ship and provides power for many vital services—steering, lighting, ventilation, cooking, heating, refrigeration, the operation of electrical and electronic devices, and the loading, aiming, and firing of the ship's guns. On steam-propelled ships, diesel engines are usually used only to power emergency equipment.

STEAM GENERATION

To generate steam, it is necessary to heat water to its boiling point and then to add a sufficient amount of heat to convert the boiling water into steam. The heat required to change boiling water into steam at the same temperature as the boiling water is called the LATENT HEAT OF VAPORIZATION. When steam condenses back to water (at the boiling point) an equal amount of heat is given off; in this case, it is called the LATENT HEAT OF CONDENSATION. The amount of heat required to convert boiling water to steam (or, on the other hand, the amount of heat given off when steam is condensed back to water at its boiling temperature) varies with the pressure under which the process takes place.

There are definite pressure-temperature relationships involved in the generation of steam. The boiling point of water is 212° F at sea level, where the atmospheric pressure is 14.7 psi. At high altitudes, where atmospheric pressure is reduced, water boils at a lower temperature. If pressure is increased, the boiling point of water is raised accordingly. In a boiler operating under pressure of 600 psig, water boils at 489° F. Thus, the boiling point of water is determined by the pressure.

It is important to note that the temperature of steam is determined by the temperature at which the water boils, as long as the process is taking place in a closed vessel or in a closed system such as a boiler. As long as the pressure remains constant, steam which is in contact with the water from which it is being formed remains at the same temperature as the boiling water. Thus, in a boiler operating under pressure of 600 psig, the temperature of the steam in the steam drum is 489° F—the same temperature as the boiling water.

The steam in the steam drum is known as SATURATED STEAM—that is, it is steam which has not been heated above the temperature of the water from which it was generated. As a matter of fact, it is impossible to raise

the temperature of saturated steam without also increasing the pressure as long as the steam is in contact with the water from which it is formed. However, the steam can be heated above its saturation temperature if it is first drawn off into another vessel, where it is no longer in contact with the water, and additional heat is applied. Steam which has been heated above its saturation temperature is known as SUPERHEATED STEAM; and the device which allows this extra heat to be added to the steam is known as a SUPERHEATER. The amount by which the temperature of superheated steam exceeds the temperature of saturated steam at the same pressure is known as the DEGREE OF SUPERHEAT. For example, if saturated steam at a pressure of 600 psig and a saturation temperature of 489° F is superheated to 789° F, its degree of superheat is 300 degrees.

Almost all naval propulsion boilers are equipped with superheaters. Superheated steam has many advantages over saturated steam for use in propulsion machinery. Because the steam is dry, it causes relatively little corrosion or erosion of piping and machinery. Also, it does not conduct heat as rapidly (and therefore does not lose heat as rapidly) as saturated steam. The use of superheated steam for propulsion purposes greatly increases the over-all efficiency of the plant, and this increased efficiency results in substantial savings in fuel consumption and in space and weight requirements.

It should be noted, however, that most auxiliary machinery is designed to operate on saturated steam. Reciprocating machinery, in particular, requires saturated steam for the lubrication of internal moving parts of the steam end. Naval boilers, therefore, are designed to produce both saturated and superheated steam.

THE STEAM-WATER CYCLE

In addition to knowing how steam is generated, you must know what happens to the steam after it leaves the

boiler. One of the best ways to learn about the steam plant on your own ship is to trace the path of steam and water, starting from the boiler and leading back to the boiler again. The steam-water cycle shown in figure 2–2 contains all the essential components of a modern shipboard steam plant. The steam is led from the steam drum, through the superheater, and then to the turbines, where the heat energy of the steam is converted into mechanical energy. The pressure and temperature of the steam decreases as the steam expands through the turbine stages and exhausts into the main condenser. In the condenser, the steam is cooled and condensed into water as it comes in contact with tubes through which sea water is flowing. The condensed steam (condensate) is then pumped through the air ejector condenser to the deaerating tank, where it is heated and deaerated. The condensate (which is now, properly speaking, feed water) is pumped by the feed booster pump to the feed pump, and from there it goes into the economizer of the boiler, where it is further heated before it goes back into the steam drum again. As shown in figure 2–2, additional feed water is brought into the condenser to replace any water which is lost from the system.

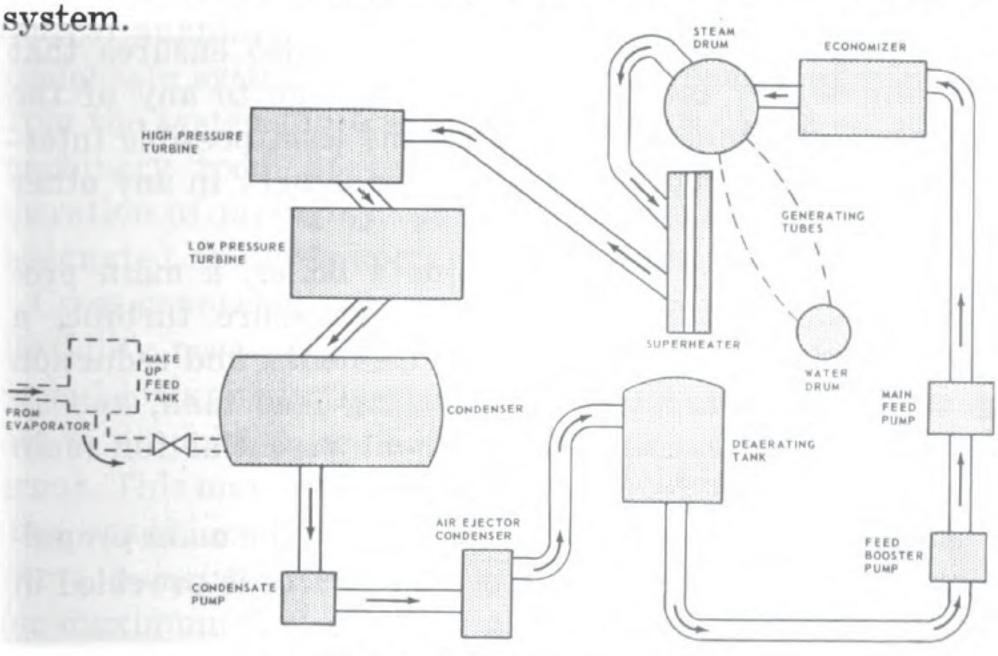


Figure 2–2.—Basic steam-water cycle.

MAIN PROPULSION PLANT

A description of the plant of a four-screw heavy cruiser, CA 139 class, will give you an idea of what constitutes the main propulsion plant of one of our newer ships. The functions of the various units and systems of this engineering plant are similar to the simpler installations you have studied in the *Fireman,* NavPers 10520–A, training course, but the general arrangement of the machinery spaces and their relationships are quite different.

The main propulsion machinery in the CA 139 class vessel is contained within four separate watertight compartments. Each compartment contains an entire power plant capable of completely independent operation. Each compartment is designated as a machinery room, and is numbered according to its driven shaft. No. 1 and No. 4 machinery rooms are located forward, and are designated as the forward machinery group. Similarly, No. 2 and No. 3 machinery rooms are located aft, and are designated as the after machinery group. The two machinery groups are separated by an auxiliary machinery room.

This arrangement of machinery provides military protection for all vital equipment. It also ensures that flooding of any compartment, or damage to any of the contained machinery, shall cause the least possible interference with the operation of the machinery in any other compartment.

Each machinery room contains a boiler, a main propulsion unit consisting of a high-pressure turbine, a low-pressure turbine with astern elements, and reduction gear; a turbogenerator, a deaerating feed tank, and all auxiliary machinery and equipment essential for main propulsion.

In addition, machinery not essential to the main propulsion plant but necessary for other services is provided in all machinery rooms.

On the CA 139 class cruiser, the piping systems and

machinery are arranged to permit operation of the main propulsion units as four isolated, completely independent power plants. The method of operation that conforms with this arrangement involves the establishment of conditions of independent operation of the piping systems and related equipment in each machinery room essential for main propulsion. This method is designated as "split-plant operation," and is intended particularly for use in enemy waters in wartime. It is also the only method to be used at ship's speed above 30 knots.

In wartime, split-plant operation precludes the possibility of damage sustained in one machinery room interfering with operations in machinery rooms remaining intact. However, provisions have been made to permit departures from split-plant operations should breakdown of auxiliary machinery, damaged or inoperative piping in a machinery room, or other operating conditions require it.

For this purpose cross-connections are incorporated only in the systems essential for the operation of vital auxiliaries and the main propulsion units. These cross-connections are provided in the main steam, 600 psi and 150 psi auxiliary steam systems, auxiliary exhaust, and condensate systems, and permit the extension of service from the systems in one machinery room to the adjacent machinery room of the same group. This method of operation of piping systems and associated equipment is designated as CROSS-CONNECTED OPERATION.

Cross-connected operation provides the additional flexibility necessary for continued operation of all main propulsion units in the event a boiler, or auxiliaries essential to propulsion, are secured in a machinery room of a group. This manner of operation is suited to normal peacetime conditions when cruising at ship's speeds below 30 knots, permitting establishment of operating conditions for maximum fuel economy and consequent extension of cruising range.

The function of the main steam system is to supply superheated steam to the main propulsion turbines, to the turbogenerators, and to the soot blowers.

The superheated steam piping is so arranged that four independent main steam systems are established; one in each machinery room. Within each group of two machinery rooms, however, cross-connecting piping is provided so that superheated steam may be applied from either boiler to either or both main propulsion units and to either or both turbogenerators. A six-inch cross connection between main propulsion units of a group permits continued operation at a ship's speed of approximately 30 knots, when only one boiler of a group is in service. A three-inch cross connection between turbogenerators permits the use of both generators of a group when only one boiler is in service, and also allows for the use of either generator with either boiler of a group when in port. Each boiler supplies superheated steam to its soot blowers directly from the superheater outlet. The main stop valve at each superheater outlet may be manually operated locally or hydraulically operated from the second deck.

Split-plant operation of the main steam system is established by securing the six-inch cross-connection between the main propulsion units of a machinery group and the three-inch cross-connection between the turbogenerators of a machinery group. This establishes one completely independent main steam system in each machinery room—shown diagrammatically in figure 2–3.

Cross-connected operation of the main steam system (fig. 2–3) will only be used when one boiler of a machinery group is secured. Under this condition, the six-inch cross-connection between the main propulsion units of the group will be in service, and the three-inch cross-connection between the turbogenerators will be secured. If, however, it is necessary to have both generators in operation, the three-inch cross-connection is also placed in service.

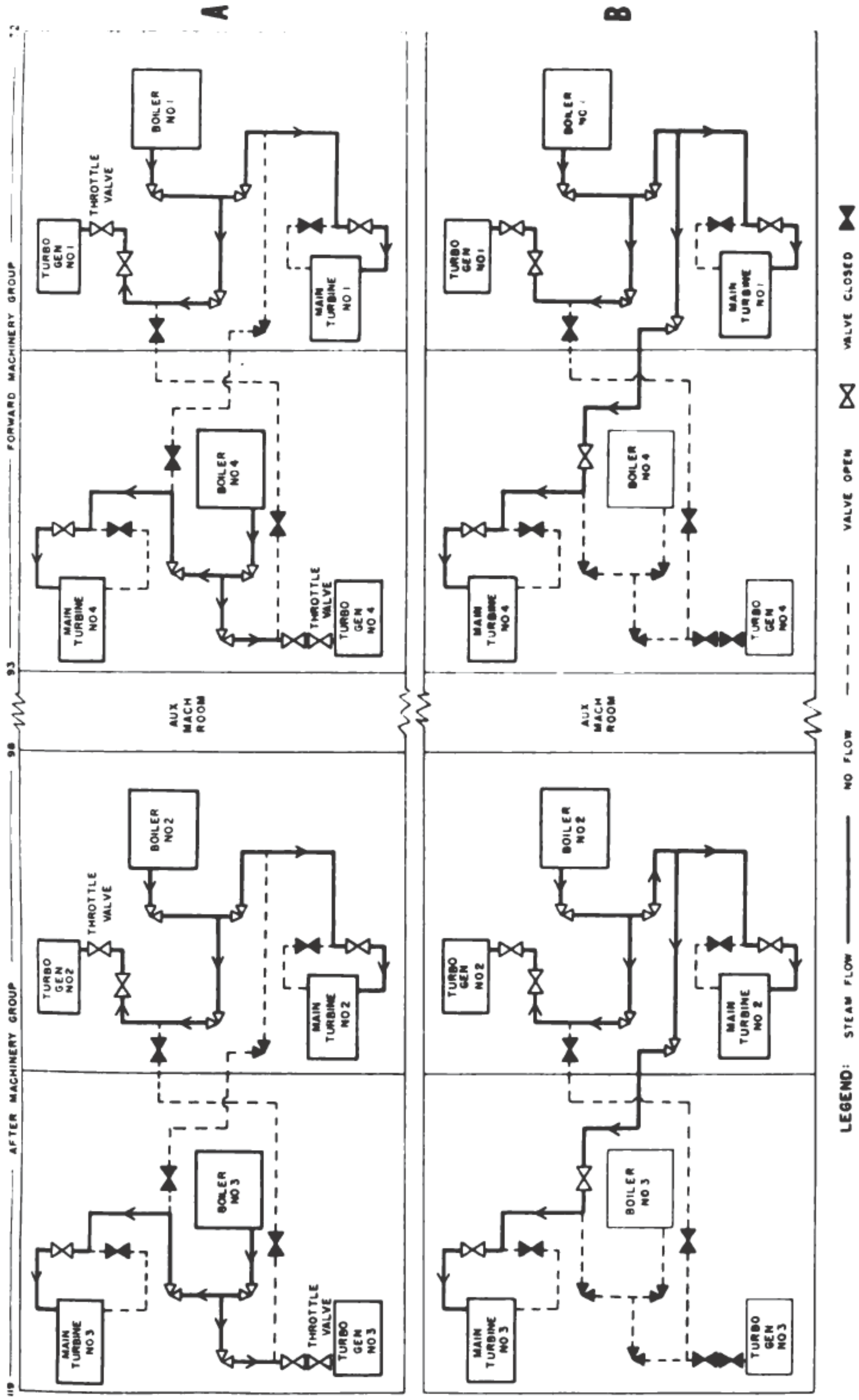


Figure 2-3.—Main steam-flow diagram of CA 139 class: (A) split-plant operation; and (B) cross-connected operation.

The normal cross-connected condition, with only one turbogenerator in each machinery group in service, is shown diagrammatically in figure 2–3B.

Safety and Control Devices

BOILER TWO-VALVE PROTECTION is provided at the superheater outlet and drum outlet of each boiler. If a boiler is secured for repairs, each pair of stop valves in the superheated steam supply to the main propulsion units, the superheated steam supply to the turbogenerators, and the saturated steam supply to the 600 psi auxiliary steam main, is closed; and the drain in the piping interconnecting each pair of valves is opened. This affords personnel entering the boiler protection against injury from steam leakage into the boiler through faulty stop valves.

Steam is delivered to the high-pressure turbine of a main propulsion unit by a manually-operated GUARDING VALVE. The guarding valve is wide open for ahead operation, and steam supply is controlled by six cam-operated steam admission valves in the turbine. Handwheels, located at the main gage board, operate a gear shaft to fully open the guarding valve, and a cam shaft to open the nozzle control valves in the required sequence. In case of emergency, when it is necessary to secure the steam to the high-pressure turbine quickly, the guarding valve is used.

Steam to the astern element of a main propulsion unit is admitted and controlled by a manually-operated astern THROTTLE VALVE. A handwheel, also located at the main gage board, operates a gear shaft to open or close the valve as required. All the steam to the astern unit passes through the body of the ahead guarding valve, but is not controlled by it.

BYPASS VALVES are provided around the guarding valve and the astern throttle valve to relieve pressure behind the valve piston, thus decreasing the unbalance of forces loading the valve gear. Operating gear is installed from each bypass valve to the main gage board where the hand-

wheels are located adjacent to the guarding valve and astern throttle handwheels. Whenever the guarding valve or astern throttle is to be placed in operation, its bypass valve must first be opened.

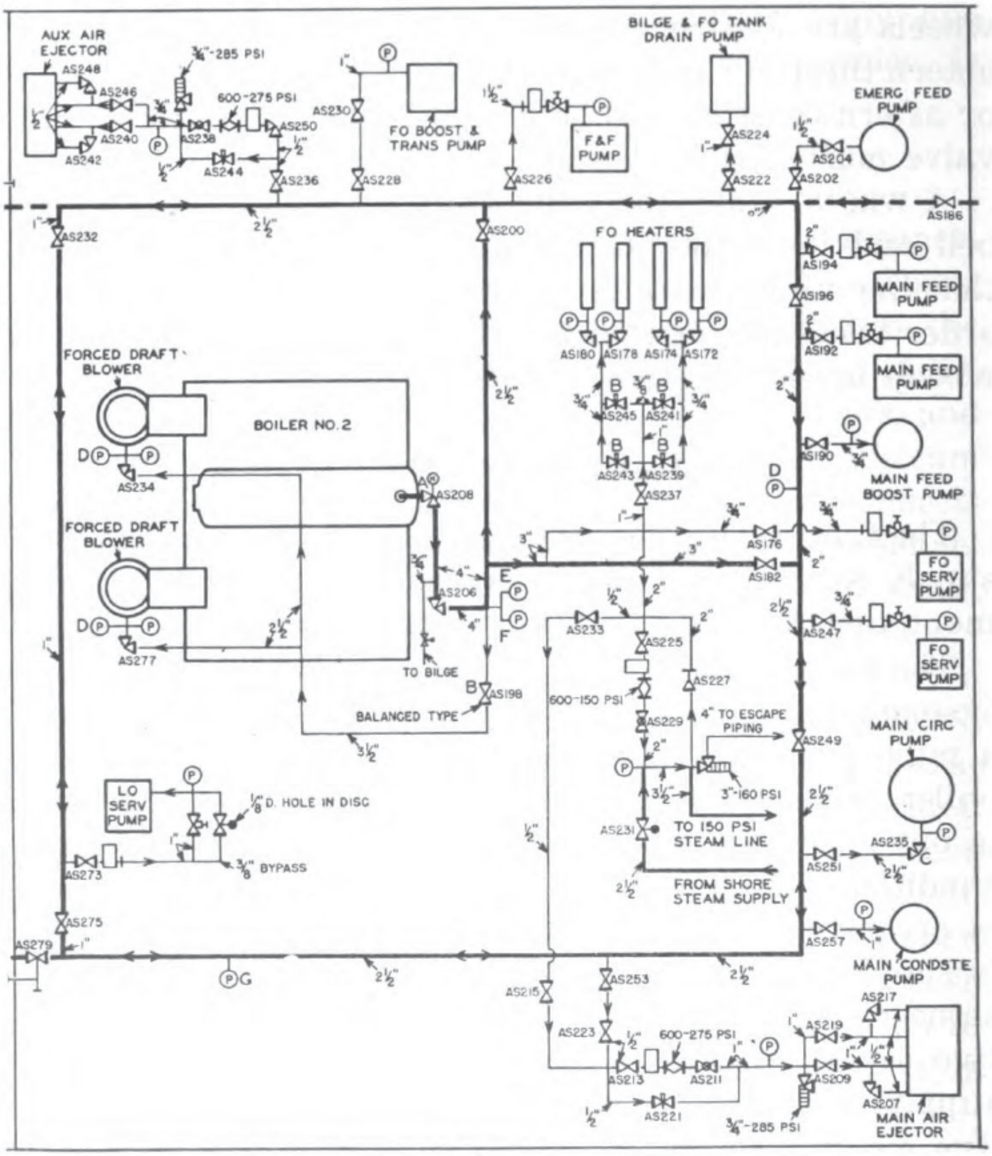
A WRONG DIRECTION INDICATOR, consisting of an alarm bell and indicating lights, gives warning in the event that the wrong valve is opened in response to the engine order telegraph, or that both the ahead and astern handwheels are accidentally opened at the same time.

600 PSI AUXILIARY STEAM SYSTEM

The function of the 600 psi auxiliary steam system is to supply saturated steam to connected auxiliaries, equipment, and reduced-pressure steam systems.

The basic design principle of the arrangement of this system is to make it possible to operate the auxiliaries of a main propulsion unit in a machinery room, when the boiler, or a section of auxiliary steam piping in that room is out of service, either because of casualty or cruising conditions. Therefore, the system in each machinery room is arranged in the form of a continuous loop. This loop is supplied at two separate points from the boiler in the same room, and is so valved between these points, that two separate sections may be established. The normal supply to the loop is via a 3-inch line, with the 2½-inch line secured. In the event of a casualty to the section of the loop connected to the 3-inch supply line, that section can be secured and the remainder of the loop supplied via the 2½-inch line. (See figure 2–4.) The loops of two adjacent machinery rooms are cross-connected at each side of the ship, thus making it possible to establish one large loop in each machinery group. A single small cross-connection is provided between the two machinery groups.

Provisions are made for supplying vital auxiliaries or equipment in each machinery room from two points in the loop system of that room. These points are located at opposite sides of the loop, or at one side of the loop and at



SYMBOLS

GLOBE STOP VALVE	GLOBE STOP CHECK VALVE
GLOBE STOP VALVE, LOCKED SHUT	NEEDLE VALVE
	GOVERNOR VALVE
ANGLE STOP VALVE	REDUCING VALVE
ANGLE STOP VALVE, HYDRAULICALLY OPERATED	RELIEF VALVE
	STEAM STRAINER
	PRESSURE GAGE

VALVES A MANUALLY OPERATED LOCALLY & HYDRAULICALLY OPERATED FROM 2ND DECK.
VALVES B OPERATED FROM FIRING AISLE
VALVES C OPERATED FROM TURBINE OPERATING PLATFORM ONLY.
GAGES D LOCATED ON BOILER GAGEBOARD.
GAGES E LOCATED ON SECONDARY CONTROL BOARD IN MACHY ROOM NO. 1.
GAGES F LOCATED ON GAGEBOARD IN CENTRAL CONTROL STATION.
GAGES G LOCATED ON MAIN GAGEBOARD

Figure 2–4.—Machinery room No. 2 of CA 139 class, showing the 600 psi auxiliary steam supply.

the supply piping to the loop. Thus, the main air ejector in each machinery room may receive steam from one side, or from the supply piping to the loop; the lubricating oil service pump may be supplied from either side; one fuel oil service pump is supplied from one side, the other from the supply piping to the loop; one main feed pump is supplied from one side, the other is supplied from the opposite side. In addition, any auxiliary or equipment in any machinery room can be supplied from the adjacent machinery room by means of either, or both, cross-connections between the two spaces. The use of the cross-connections and alternate sources of supply, individually or in combination, permits many piping arrangements to be established to meet the various conditions arising from damage, maintenance needs, or low-speed cruising operation.

The $1\frac{1}{4}$-inch cross-connection between the two machinery groups permits the supply of steam from any machinery room to the distilling unit air ejectors in the auxiliary machinery room. In addition, this cross-connection is used for lighting-off purposes to supply a dead machinery room from another space already in service.

Shore steam (fig. 2–4) may be supplied to this system via the 150 psi auxiliary steam system and the 2-inch bypass line around the 600–150 psi reducing valves in machinery rooms Nos. 1 and 2. A stop-check valve in this line permits flow to the 600 psi system only. This arrangement permits the supply of low-pressure shore steam to the fuel oil heaters for lighting-off purposes.

Steam is supplied to the main air ejectors through a $\frac{1}{2}$-inch 600–275 psi reducing valve, or in the event of failure of the reducing valve, through a bypass and $\frac{1}{2}$-inch needle valve. A relief valve, set at 285 psi, protects the air ejectors from excessive pressure.

Steam is supplied to the auxiliary air ejectors through a $\frac{1}{2}$-inch, 600–275 psi reducing valve. Provisions for bypassing and protection against excessive pressure are the same as those for the main air ejectors.

The distilling unit air ejectors are supplied via a $\frac{1}{2}$-inch, 600–150 psi reducing valve, or a $\frac{1}{2}$-inch needle valve and bypass.

The steam piping to the four fuel oil heaters in each machinery room is arranged to supply the heaters in pairs. Each pair of heaters may be supplied via a $\frac{3}{4}$-inch needle valve for heavy heating loads, or a $\frac{3}{8}$-inch needle valve for light heating loads. All needle control valves are operable from the firing aisle.

The steam supply to the main lubricating oil pump turbine in each machinery room is controlled by a constant-pressure regulator. A $\frac{3}{8}$-inch bypass valve is provided around the regulator to permit the lubricating oil pump to rotate at idling speed when in the "standby" condition. A $\frac{1}{8}$-inch hole is drilled in the disk of the bypass valve to provide the steam necessary for idling, and the valve is closed under all service conditions.

Steam is supplied to the two forced draft blowers in each machinery room through a common balanced-type control valve to the individual throttle valve at each unit.

150 PSI AUXILIARY STEAM SYSTEM

The function of the low pressure steam system is to supply 150 psi steam to auxiliary equipment and to reducing valves for low-pressure steam services. The 150 psi steam main extends from machinery room No. 1 to machinery room No. 3 and interconnects all intervening machinery spaces. Steam is supplied to this main through four 2-inch 600–150 psi reducing valves, one in each machinery room. Connections for providing shore steam to this system are located on both the port and starboard sides on the main deck. Steam is supplied from the 150 psi main to the various low-pressure steam services in each machinery room through branch lines in the same room. A single branch line from each extremity of the main supplies the services required forward and aft of the main machinery groups. Figure 2–5 shows the dia-

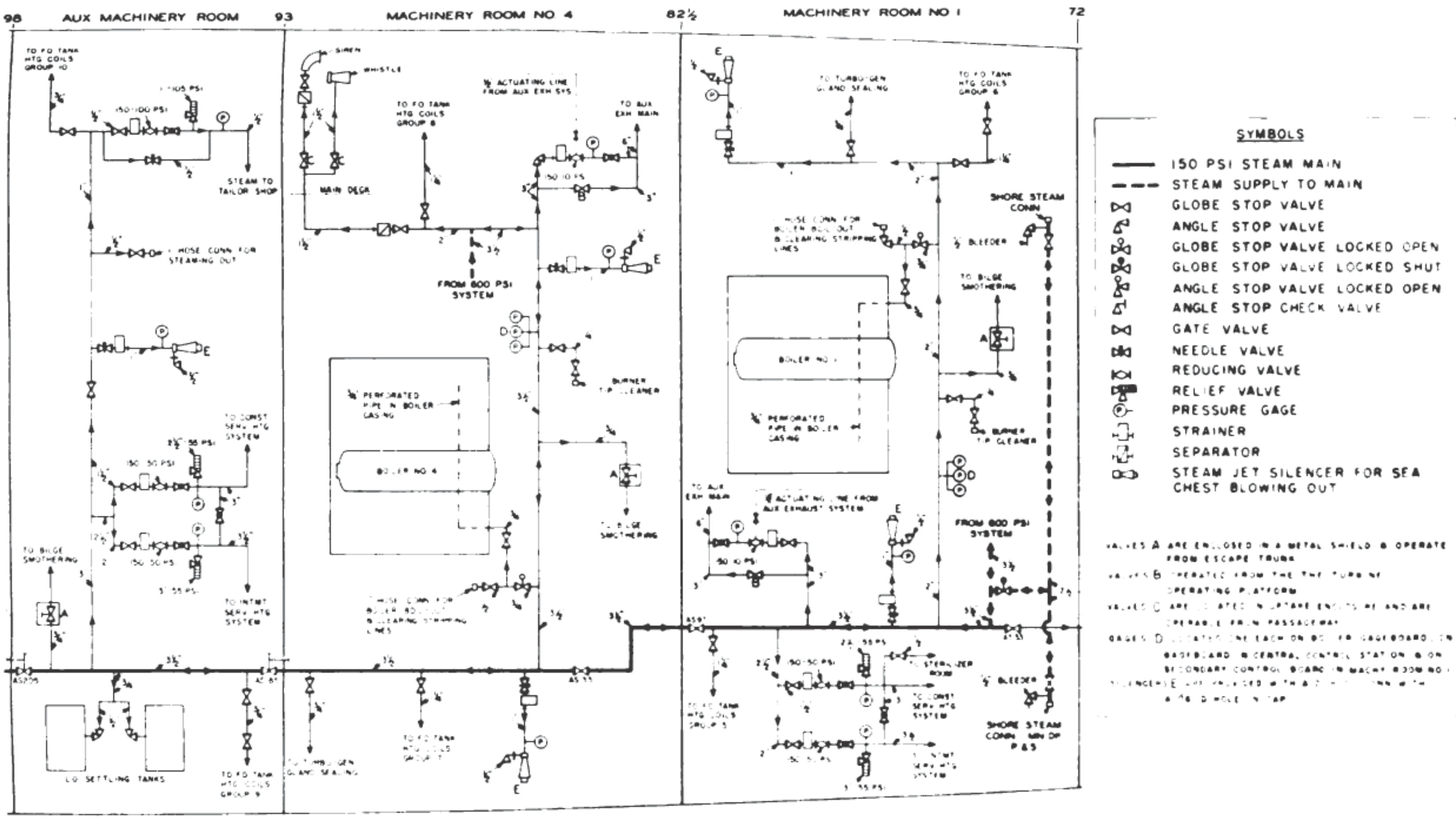


Figure 2–5.—Machinery rooms No. 1 and No. 4 of CA 139 class, showing the 150 psi auxiliary steam system.

grammatic arrangements for machinery rooms No. 1 and No. 4.

Cutout valves are provided at each bulkhead to permit subdivision of the steam main as required. Four independent 150 psi systems may be established by the proper use of these valves, with each system supplied by its own 600–150 psi reducing valve. If 150 psi steam is required in the auxiliary machinery room under these conditions, it is necessary to extend either adjacent system to include that room. The bulkhead cutout valves in the auxiliary machinery room may be operated locally or from the adjacent machinery room. Also, if 150 psi steam is required for services forward of machinery room No. 1 or aft of machinery room No. 3, the system in these rooms can be extended by opening the necessary bulkhead cutout valves.

In each machinery room, branch lines from the section of the 150 psi steam main in that room, supply the following services:

1. Auxiliary exhaust make-up via a 3-inch 150–10 psi reducing valve. In the event of derangement to this valve, makeup to the auxiliary exhaust system may be added by manual control of a bypass valve operable from the turbine platform.

2. Turbogenerator gland sealing steam via an automatic steam seal regulator located at the generator turbine.

3. Fuel oil tank heating coils via steam supply manifolds located port and starboard in each room. A stop valve for each fuel oil tank at that side of the room is incorporated in each manifold. A similar installation of drain manifolds located adjacent to the supply manifolds permits easy completion of the steam circuit required for oil heating.

4. Bilge smothering system via a stop valve operable from the escape trunk. The handwheel is enclosed in a metal shield, the door of which can only be opened by breaking a lead seal. An instruction plate on this door

gives warning that this valve is only to be used in an emergency. This system provides steam for smothering otherwise uncontrollable bilge fires, and should only be used as a last resort and after all personnel have left the room.

5. Perforated pipe in boiler casing via a locked-open root valve and a stop valve operable from the firing aisle. This pipe provides steam to smother a fire caused by an accumulation of oil drippings in the casing below the burners.

6. Burner tip cleaning via a root valve at the 150 psi system and a stop valve at the boiler work bench.

7. Boiler boil-out hose connection via a stop valve and a locked-open root valve. A $\frac{1}{16}$-inch hole is provided in the hose connection cap to serve as an indication of valve leakage.

8. Fuel oil stripping line steaming out via the boiler boil-out hose connection and temporary hose to a similar connection on the stripping line in the same room.

9. Sea chest blowing-out hose connections port and starboard in each room via a locally-controlled needle valve and a strainer. A steam jet silencer is provided at each connection. Steam is supplied to the suction sea chest to be cleaned through the silencer, which, by eductor action, takes air suction from the machinery room via a manually-operated stop-check valve. The mixture of air and steam is led to the sea chest through a temporary hose. The addition of air to the steam supply decreases the noise normally associated with sea chest blowing-out operations. It also eliminates, to a great extent, the water hammer that previously occurred upon securing the steam by cushioning the collapse of steam bubbles in the sea chest.

Additional services, not common to all machinery rooms, are supplied by the 150 psi auxiliary steam system, as follows:

1. Whistle and siren via a common $1\frac{1}{2}$-inch supply line from machinery room No. 4. A steam separator is pro-

vided in this line to prevent condensate from passing through the line. The common line divides into two 1½-inch lines in the uptake space, one line supplying the whistle, the other supplying the siren. Stop valves in these lines are located just above the main deck, and are operable from the main deck passageway. Another separator is installed at the siren to further ensure against the passage of condensate to the unit.

2. Laundry via a 1¼-inch, 150–100 psi reducing valve in machinery room No. 3. A 1-inch, 105 psi relief valve is provided for protection against excessive pressure, and a locally-operated bypass valve is installed for use when the reducing valve is deranged.

3. Tailor shop via a ½-inch, 150–100 psi reducing valve. A bypass permits the continued supply of steam under manual control of a needle valve should it be necessary to secure the reducing valve. A 1-inch, 105 psi relief valve protects the supply piping to the tailor shop from excessive pressure.

4. Steam, at 150 psi, may be supplied to shore from any machinery room via the steam main to either No. 1 or No. 2 machinery rooms through the 2½-inch supply lines from these rooms to the shore steam deck connections, and then to shore through temporary hose. A warning plate at the deck connections instructs personnel to open the ½-inch bleeder valve before disconnecting the hose to prevent possible injury from steam remaining in the hose after securing. This warning applies when either supplying or receiving shore steam.

5. Constant-service steam heating system via three 1½-inch, 150–50 psi reducing valves. These valves are intentionally located forward, amidships, and aft through the machinery spaces. Thus, if desired, the reducing valve in machinery room No. 1 may supply all the constant-service heating steam requirements for the forward section of the ship, the reducing valve in the auxiliary machinery room may supply all the requirements amidships, and the reducing valve in machinery room No. 3

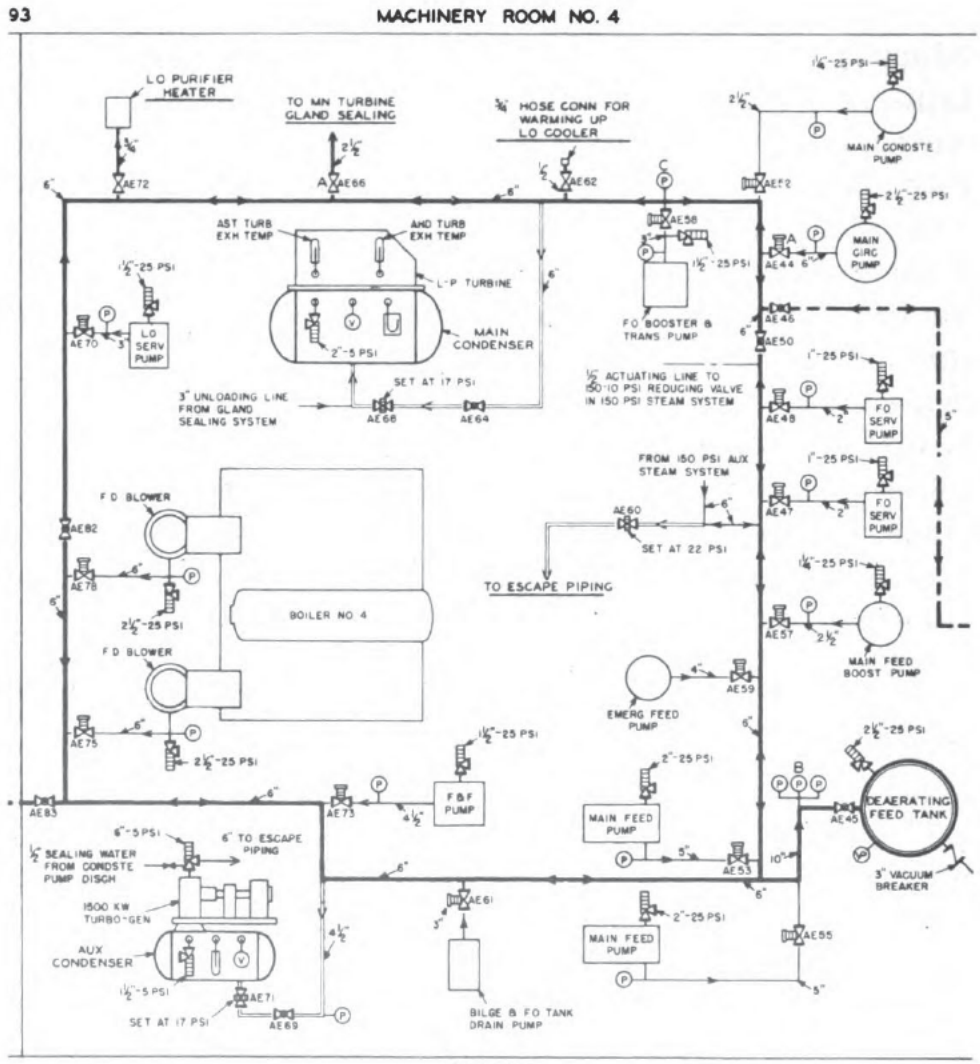
may supply all the requirements aft. However, steam heating demands should normally only require two reducing valves in service, and the heating system piping is so arranged that any reducing valve, or any pair of reducing valves, may supply any service requiring constant-service heating steam. A 2½-inch, 55 psi relief valve located at each reducing valve outlet protects the system from excessive pressure. A ½-inch valved supply line to the sterilizer room (sick bay) is provided at the outlet of the reducing valve in machinery room No. 1. In the event of derangement of a reducing valve, steam may be supplied to its normally connected services via a 3-inch cross-connection from the outlet of the adjacent intermittent-service steam heating system reducing valve.

6. Intermittent-service steam heating system via three 2-inch, 150–50 psi reducing valves. These valves are located adjacent to the constant-service steam heating system reducing valves, and have the same arrangements to serve the intermittent-service steam heating requirements. A 3-inch, 55 psi relief valve protects this system from excessive pressure. The same cross-connection mentioned in the constant-service steam heating system, may receive constant-service heating steam and supply it to the intermittent-service heating system in the event of derangement of an intermittent-service heating system reducing valve.

AUXILIARY EXHAUST STEAM SYSTEM

The function of the auxiliary exhaust steam system is to receive exhaust from all steam-driven auxiliaries and to utilize this exhaust to supply the deaerating feed heaters, the distilling units, and the turbine glands for sealing.

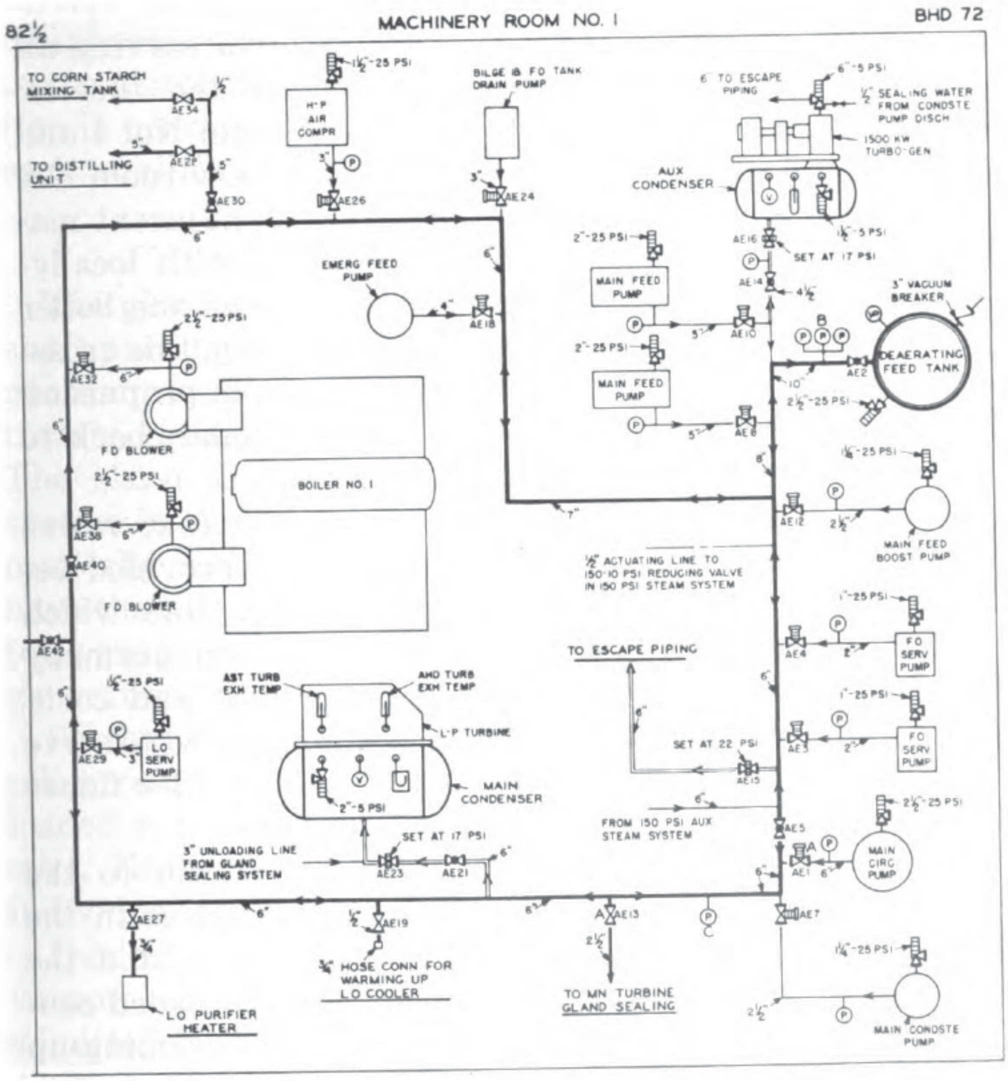
The auxiliary exhaust piping is arranged in the form of a complete loop in each machinery room, with branch lines from each auxiliary to this main. Figure 2–6 illustrates these branch lines and the auxiliary exhaust piping found in machinery rooms No. 1 and No. 4 on the CA 139



SYMBOLS

— —	CROSS-CONNECTION		RELIEF VALVE
═	UNLOADING LINE		PRESSURE GAGE
	GLOBE STOP VALVE		VACUUM GAGE
	GATE VALVE		VACUUM-PRESSURE GAGE
	SWING CHECK VALVE		THERMOMETER, DISTANT READING
	BACK PRESSURE UNLOADING VALVE		THERMOMETER, DIRECT READING
	LIFT CHECK VALVE, SPRING LOADED		ABSOLUTE PRESSURE GAGE

Figure 2-6.—Machinery rooms No. 1 and No. 4 of CA 139 class, showing the auxiliary exhaust steam system.



VALVES A OPERATED FROM TURBINE OPERATING PLATFORM ONLY.
GAGES B LOCATED ONE EACH ON BOILER GAGEBOARD, ON GAGEBOARD IN CENTRAL CONTROL STATION & ON SECONDARY CONTROL BOARD IN MACHY ROOM NO I
GAGES C LOCATED ON MAIN GAGEBOARD.

Figure 2–6.—Machinery rooms No. 1 and No. 4 of CA 139 class, showing the auxiliary exhaust steam system—Continued.

class. Each loop is provided with a pair of isolating valves which when closed divide the loop into two sections, one serving the auxiliaries directly associated with the operation of the propulsion turbines, and the other serving all other auxiliaries. (Exceptions to this are the fuel oil booster and transfer pump in machinery room No. 4 and the high-pressure air compressor in machinery room No. 3.) A cross-connection is provided between adjacent machinery rooms of each group and is fitted with locally-operated cutout valves at each end. Whenever one boiler is serving the two propulsion units of its group, this cross-connection permits the return of exhaust from propulsion auxiliaries in the room with the secured boiler, back to the room in which the boiler is in operation.

A cross-connection with locally-operated cutout valves at each end in the machinery rooms is also provided between the forward and after groups. This line which passes through the auxiliary machinery room normally supplies exhaust steam to the distilling unit and cornstarch tanks in this room only, and is not intended to serve as an exhaust transfer main between groups. (See figure 2–6 showing machinery room No. 1.)

The auxiliary exhaust system supplies steam to the deaerating feed tanks via automatic check valves in the tanks; the distilling units via reducing valves; and the main turbine gland sealing system via weight-loaded control valves. Provision is also made to supply warming-up steam to the lube oil coolers via a hose connection, and to the lube oil purifier heaters.

The operating pressure limits of the auxiliary exhaust system are automatically maintained between a minimum of 10 psi and a maximum of 25 psi. As the demand for auxiliary exhaust is increased, the system pressure will drop to about 10 psi, at which pressure the make-up reducing valve from the 150 psi auxiliary steam system will open to augment the exhaust from the auxiliaries. As the demand for auxiliary exhaust is decreased, the system pressure will rise to about 17 psi, at which pressure the

excess exhaust is unloaded to the main or auxiliary condenser via an automatic unloading valve at each condenser. If the system pressure rises to 22 psi, the atmospheric relief valve will open to discharge the excess to the atmosphere via the escape piping. Further protection is provided by relief valves on the exhaust casing of each auxiliary turbine set at 25 psi.

GLAND SEALING SYSTEM

The gland sealing systems supply sealing steam to the shaft packings of the main propulsion turbines and turbogenerators. This prevents the leakage of air into the turbine casings with resultant loss of condenser vacuum. The gland sealing steam piping forms an independent system in each machinery room, as illustrated diagrammatically in figure 2–7; the other three machinery rooms have the same piping system. Separate gland sealing systems are provided for the main turbines and for the turbogenerators.

Sealing steam for the main propulsion turbines is supplied from the auxiliary exhaust system through a weight-loaded reducing valve set to maintain 1 psi outlet pressure. Each gland is supplied through a stop valve for individual control of sealing steam.

During maneuvering and low-speed conditions, when a vacuum exists in the turbine casings, sealing steam is admitted to the system from the auxiliary exhaust main. At higher speeds, the pressures are above atmospheric at the glands of the high-pressure turbine and below atmospheric at the glands of the low-pressure turbine. Steam from the high-pressure turbine will leak off, and together with leakoff from the control valve stems will supply sealing steam to the glands of the low-pressure turbine.

When the sealing steam pressure exceeds 1 psi, the weight-loaded reducing valve will close automatically. A manually-operated valve is provided in the system to unload to the condenser.

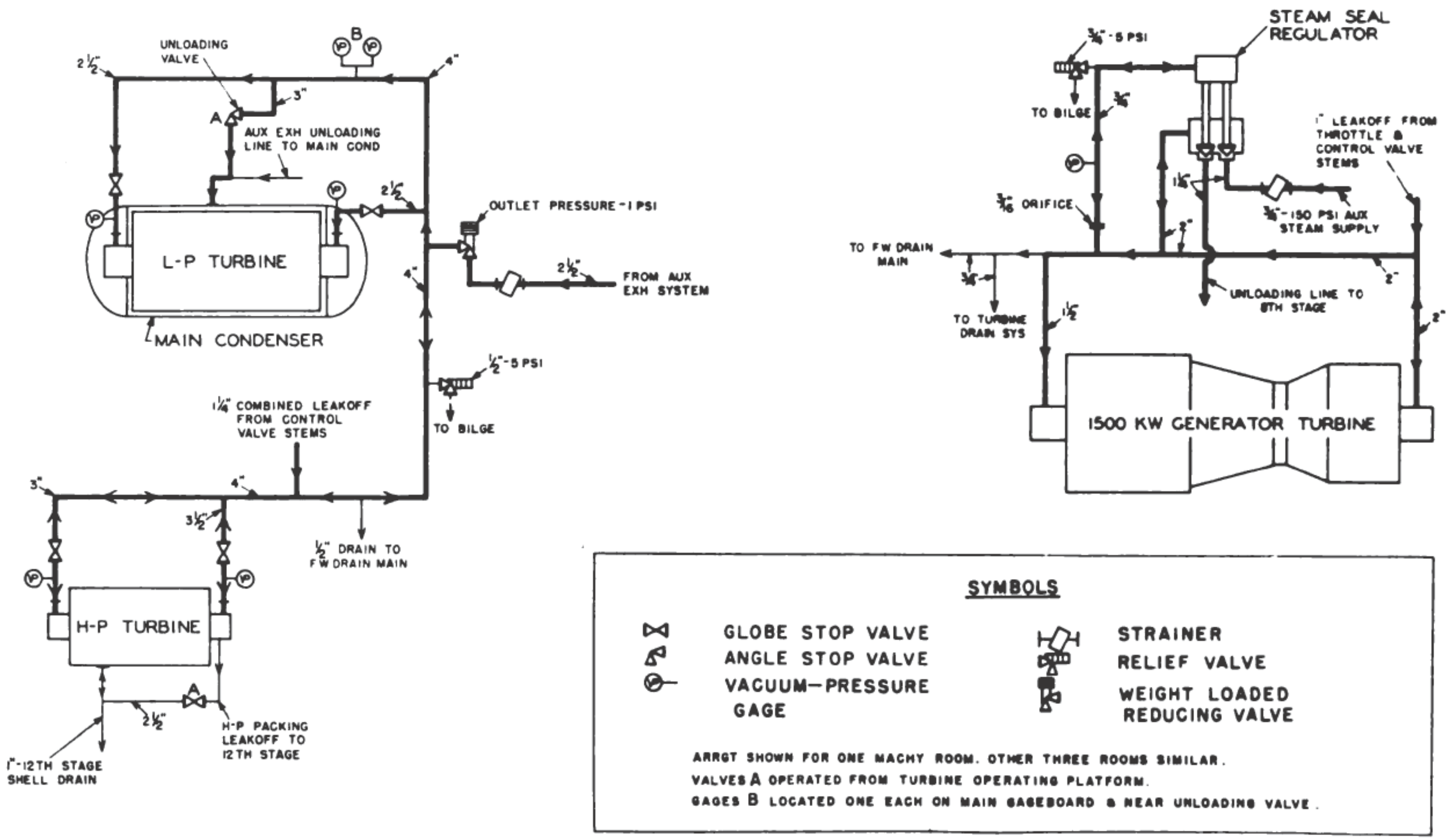


Figure 2-7.—Gland sealing system of CA 139 class vessel.

The sealing steam piping for the main turbines is protected against excessive pressures by a relief valve set at 5 psi. A drain line from the system to the fresh water drain collecting tank via a thermostatic trap assures drainage of the system.

Sealing steam for the turbogenerator is supplied from the 150 psi auxiliary steam system through a steam seal regulator which maintains a sealing steam pressure of 1 to 2 psi at each gland. During starting, stopping, and low-load conditions, a vacuum exists in the turbine, and sealing steam is admitted to the system via the steam seal regulator. At full load, the turbine internal pressure is above atmospheric at the high-pressure end, and below atmospheric at the exhaust end. Leakage from the high-pressure packing is more than enough to seal the low-pressure packing. The regulator acts to shut off the 150 psi steam supply and to open the valve which discharges the excess steam to the eighth stage of the turbine. Leakoff from the throttle and control valve stems also discharges to the steam sealing system.

The sealing steam piping for the turbogenerator is protected by a relief valve set at 5 psi. A drain line from the system to the fresh water drain collecting tank via a thermostatic trap assures adequate drainage of the system.

GLAND EXHAUST SYSTEM

The gland exhaust piping system permits removal of any escaping vapors which leak off from the shaft packing glands of the main propulsion turbines and turbogenerators. In addition, vapors are directed to the gland leakoff condenser by means of the gland exhaust fan.

The gland exhaust piping forms an independent system in each machinery room and as illustrated diagrammatically in figure 2–8, serves both the main turbines and the turbogenerators. The gland exhaust fan draws the gland leakoff steam through the gland leakoff condenser,

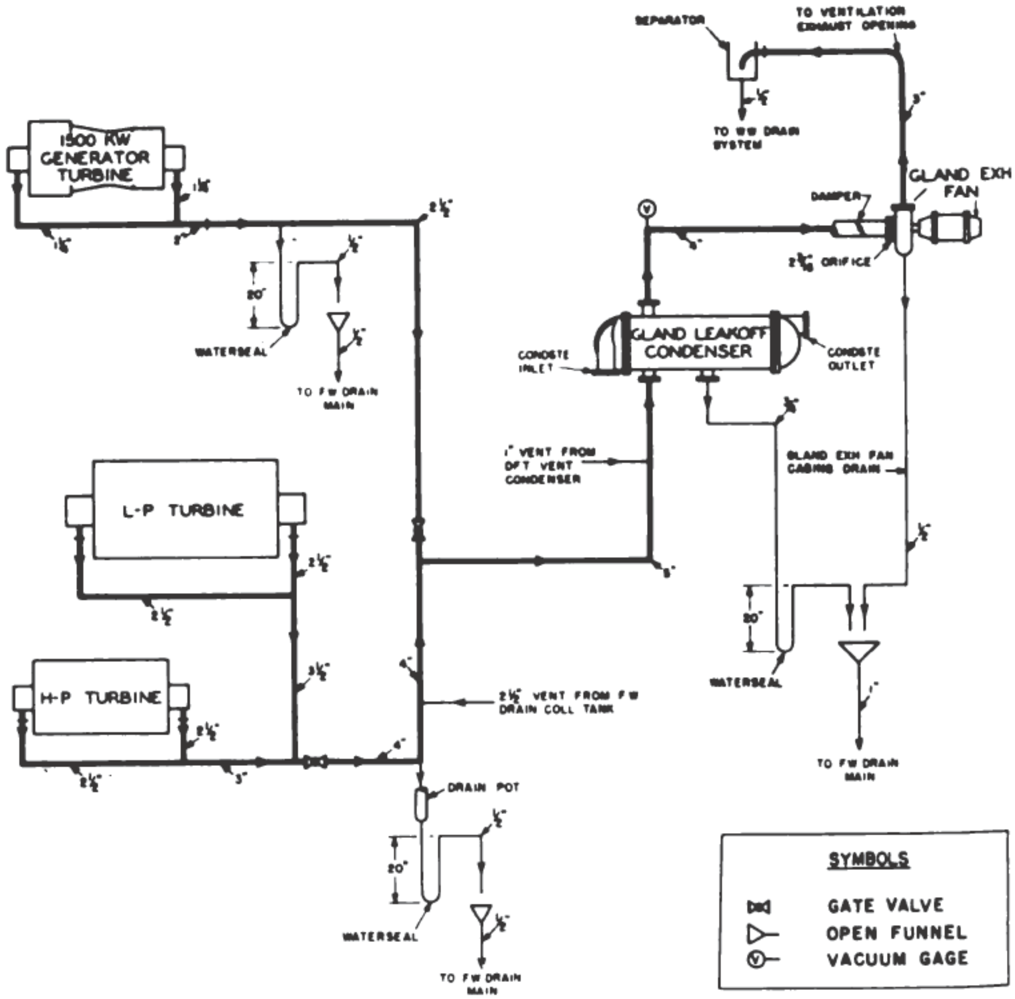


Figure 2-8.—Gland exhaust system of a CA 139 class vessel.

where the steam is condensed, and the noncondensible gases are discharged to a ventilation exhaust opening by the fan. Vapors from the deaerating feed tank vent condenser and fresh water drain collecting tank are also drawn into the gland leakoff condenser. The gland exhaust fan suction is fitted with a damper for adjusting the vacuum at the glands. The fan casing drains through an open funnel to the fresh water drain system.

The low points of the system and of the gland leakoff condenser are continuously drained through water loop-seals and open funnels to the fresh water drain system. The water seals prevent air from being drawn into the gland exhaust piping through the drain lines.

TURBINE DRAIN SYSTEM

The turbine drain system removes any condensate which may collect at low points in the turbine, at throttle valves, control valves, and at the valve chest.

The turbine drain piping is independent in each machinery room and is illustrated diagrammatically in figure 2–9. Separate systems are provided for the main turbines and for the turbogenerator.

The 1st, 4th, 6th, and 12th stages of the high-pressure turbine each drain into a common drain manifold which discharges to the main condenser. The valve chest drain of the high-pressure turbine also discharges to this drain

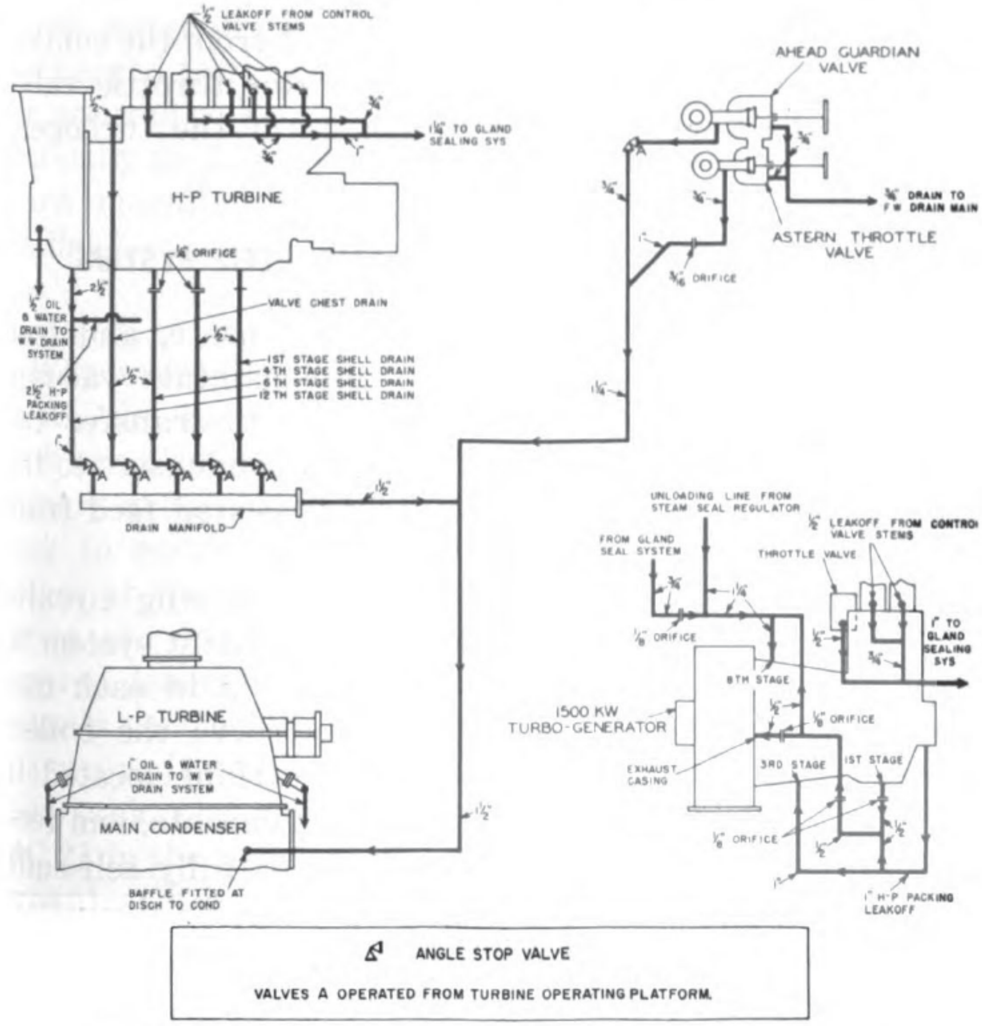


Figure 2–9.—Turbine drain system of a CA 139 class vessel.

manifold. The valve in the 12th stage drain line is provided with a drilled hole in the disk to permit continued draining of several stages under normal operating conditions. The combined leakoff from the high-pressure turbine control valve stems discharge to the gland sealing system for the main propulsion turbines.

The low-pressure turbine casing drains directly to the main condenser. Oil and water leakage from each end of this turbine and the high-pressure turbine, drains to the waste water system. Drains from above the seats of the ahead guarding valve and the astern throttle valve are discharged to the fresh water drain system, and drains from below the seats of these valves drain to the main condenser. The turbogenerator casing drains directly to the auxiliary condenser. Leakoff from the control valve stems and from the turbogenerator throttle valve discharge to the gland sealing system of the turbogenerator.

AIR EJECTOR, CONDENSATE, AND FEED SYSTEM

The function of the air ejector, condensate, and feed system is threefold: to establish and maintain vacuum in the main and auxiliary condensers; to transfer the condensate from the main and auxiliary condensers to the deaerating feed heaters; and to deliver heated feed from the deaerating feed heaters to the boilers.

The air ejector, condensate, and feed piping circuits are arranged to form a completely independent system in each machinery room. Each piping system in each machinery room is basically intended to serve the boiler, turbogenerator, and main propulsion turbine located in the same room. Thus, the air ejector, condensate, and feed piping system in each machinery room is fully self-sufficient, and capable of maintaining its function regardless of the condition of the duplicate systems in the other machinery rooms. However, a condensate cross-connection is provided between adjacent machinery rooms of a

group. This cross-connection is fitted with locally-operated cutout valves at each end.

Only the condensate system lends itself to more than one method of operation. The feed system is self-contained in each machinery room, and therefore permits only split-plant operation under all conditions.

Split-Plant Operation

Whenever four boilers are in service, split-plant operation of the condensate system is required. The valves at the extremities of the cross-connection in each machinery group are closed. All condensate in each room is discharged to the deaerating feed tank of the same room. Fresh water drains and evaporator tube nest drains are discharged to the condensate system through the body of the secured valve. This arrangement is shown diagrammatically in figure 2–10, and is characteristic of the forward machinery group (the aft machinery group is similar).

Cross-Plant Operation

Whenever one boiler in each machinery group is secured, the associated feed system and deaerating feed tank are also secured. Therefore, all condensate of a machinery group must be discharged to the deaerating feed tank in service in that group. To accomplish this, the valves at the extremities of the cross-connection in each group are opened and the condensate inlet valve to the secured deaerating feed tank is closed. In order that condensate recirculation be available for the main and auxiliary air ejectors in the room with the secured deaerating feed tank, the vent condenser bypass valve (MC 12 or MC 21 in the forward group, MC 60 or MC 65 in the after group) at the secured tank is opened, and the stop-check valve (MC 8 or MC 17 in the forward group, MC 48 or MC 71 in the after group) in the recirculating line is closed at the secured tank. This arrangement is shown diagrammatically in figure 2–10.

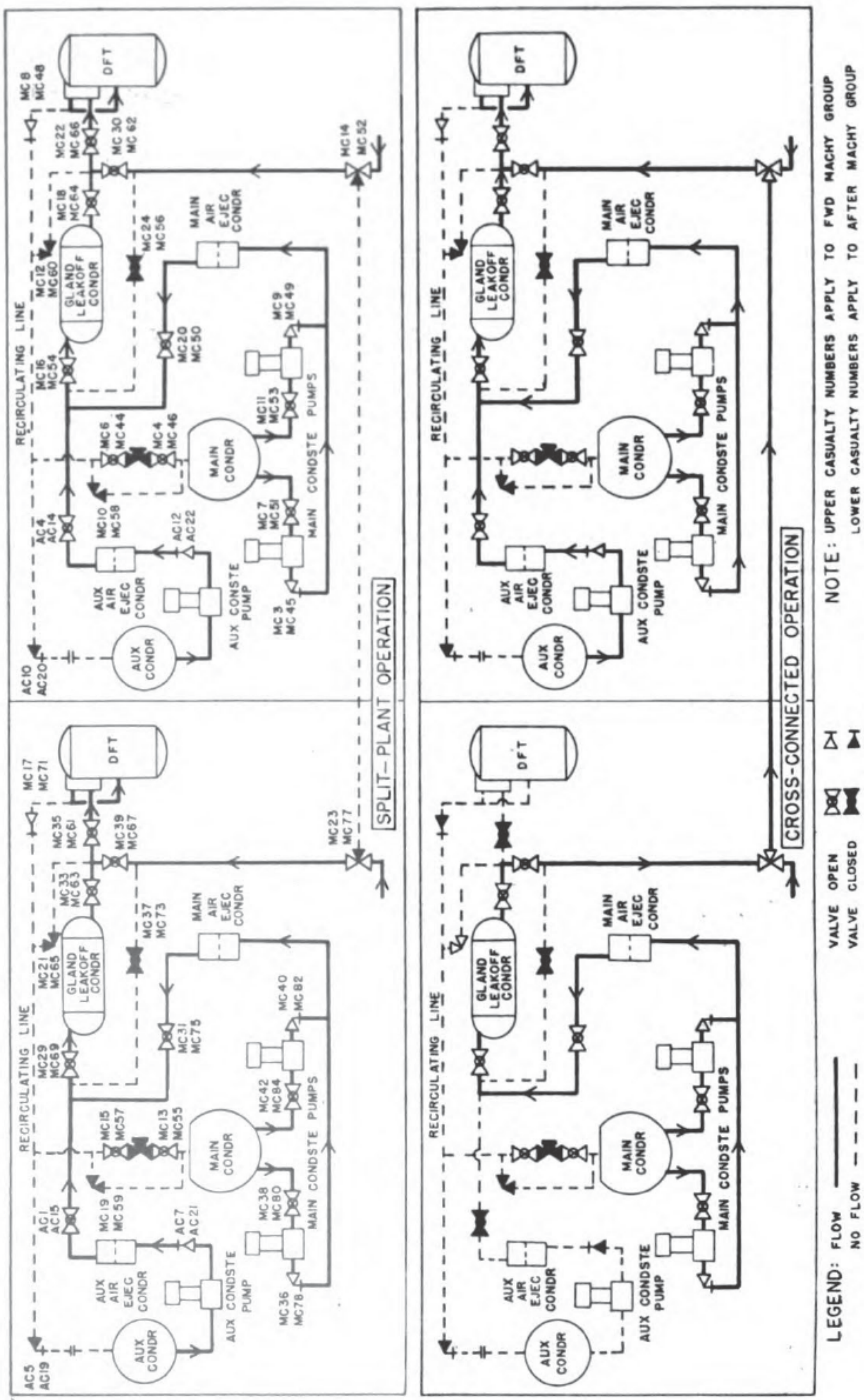


Figure 2-10.—Condensate piping of forward machinery group of a CA 139 class vessel.

Air Ejector Piping

The first-stage jets of the twin two-stage main air ejectors take air and vapor suction directly from the main condenser and discharge this mixture to the main air ejector inter-condenser. In turn, the second-stage jets take air and vapor suction from the inter-condenser and discharge to the after-condenser. The vapor which is condensed in the inter-condenser by the main condensate flowing through the tubes, drains back to the main condenser via a loopseal. The vapor which is condensed in the after-condenser, drains to the fresh water drain collecting system. Any noncondensible air and vapor remaining in the after-condenser is discharged to the atmosphere via a vent. (See figure 2–11.)

The auxiliary air ejector piping arrangement is identical to the main air ejector piping just described.

Condensate Piping

Main condensate pumps take suction from the main condenser and discharge through the main air ejector inter- and after-condensers. The auxiliary condensate pump takes suction from the auxiliary condenser and discharges to the auxiliary air ejector inter- and after-condenser. The main condensate leaving the main air ejector condenser and the auxiliary condensate leaving the auxiliary air ejector condenser are then combined and discharge through the gland leakoff condenser, to the deaerating feed heater via the vent condenser. In addition to the condensate from the main and auxiliary condenser, the fresh water drain and transfer pump in each machinery room discharges the fresh water drains accumulated by the fresh water drain collecting system to the condensate system at a point after the gland leakoff condenser.

In machinery rooms Nos. 1 and 2, the first-effect tube nest drains from the distilling units are combined with the discharge from the fresh water drain collecting tank pump. The combined condensate, fresh water drains, and

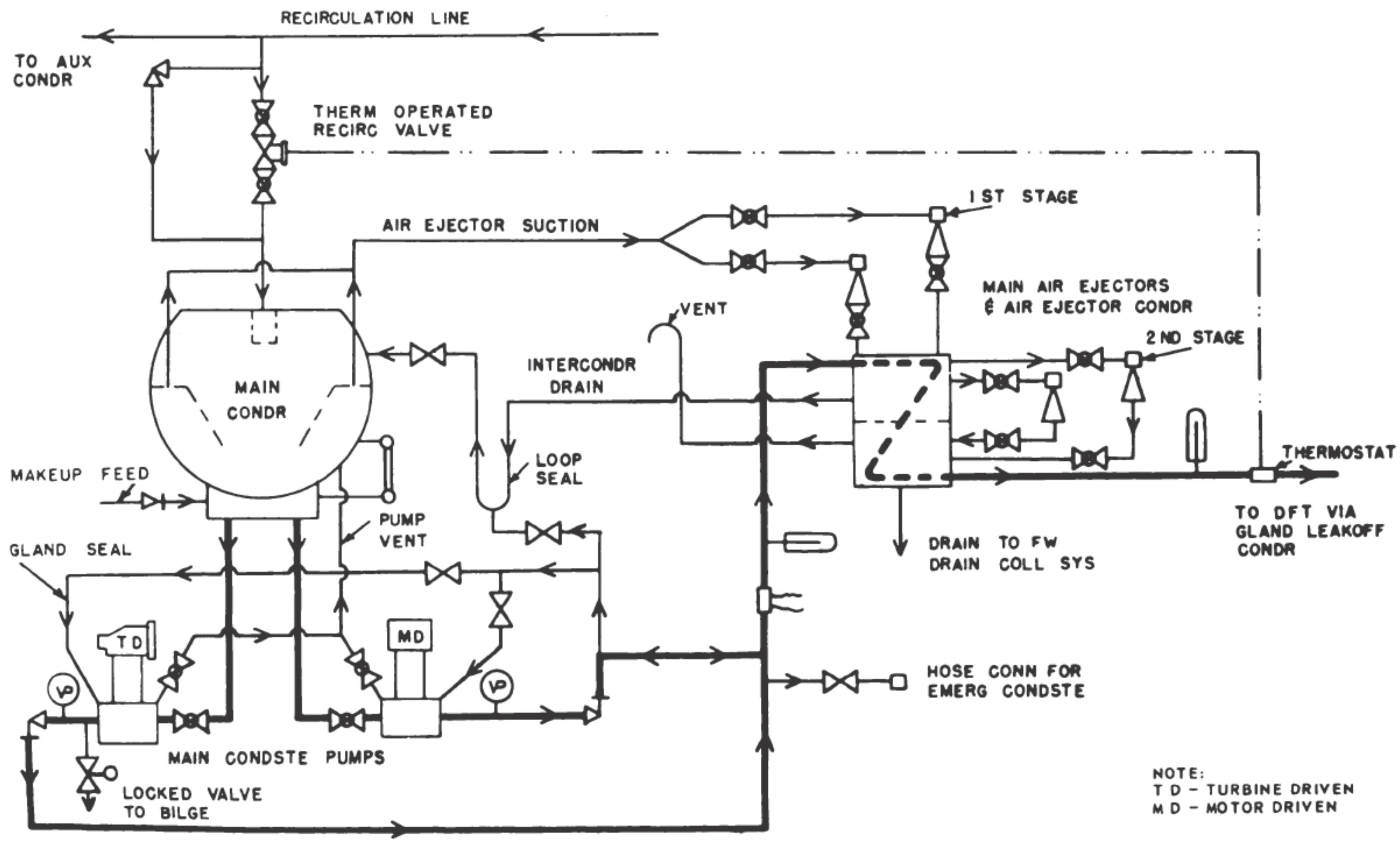


Figure 2-11.—Piping at main condenser, condensate pumps, and air ejectors of a CA 139 class vessel.

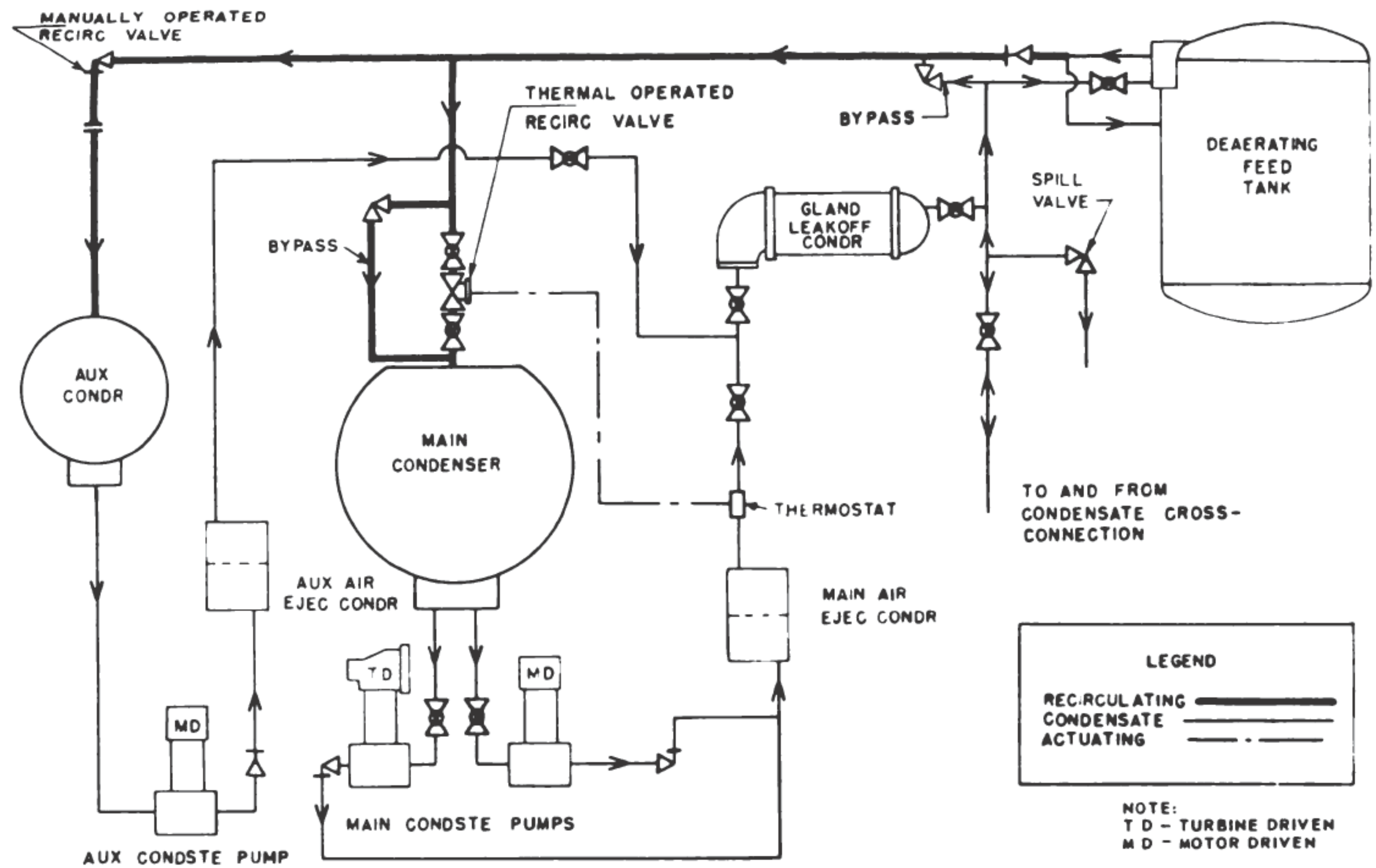


Figure 2-12.—Condensate recirculation piping on a CA 139 class vessel.

tube nest drains are delivered to the deaerating feed tank through the vent condenser. In the deaerating feed tank, the condensate and drains are broken up into sprays by nozzles, and heated by means of auxiliary exhaust steam. The heated water then drains to the bottom of the tank and provides the feed for the boilers.

A recirculating line from the vent condenser outlet (fig. 2–12) to each condenser is provided to permit the return of a portion of the condensate to the condenser during light load or standby conditions. In addition, the recirculating line augments the condensate from the turbine in order to more effectively condense the air ejector steam which remains constant regardless of load. Main condensate recirculation is controlled automatically by a thermostatically operated regulating valve in the recirculating line. Auxiliary condensate recirculation is controlled manually by a stop valve.

Feed Piping

The feed booster pumps take suction from the bottom of the deaerating feed tank and discharge to the main feed pump and emergency feed pump suctions (fig. 2–13). The main feed pumps discharge to the boiler via the main feed line. The emergency feed pump, normally for service in port, discharges to the boiler via the auxiliary feed line. Feed enters the boiler either through the main or the auxiliary feed line via the boiler feed water regulator.

STEAM, FRESH WATER, AND WASTE WATER DRAIN SYSTEMS

The steam and fresh water, and waste water drain systems are designed to provide adequate drainage from all steam-using equipment, steam piping and fittings, and to utilize these drains in the feed system, if clean, or to discharge the drains overboard, if contaminated. The drain systems may be separated into the following:

1. Steam drain main.
2. Oil heating drain main.

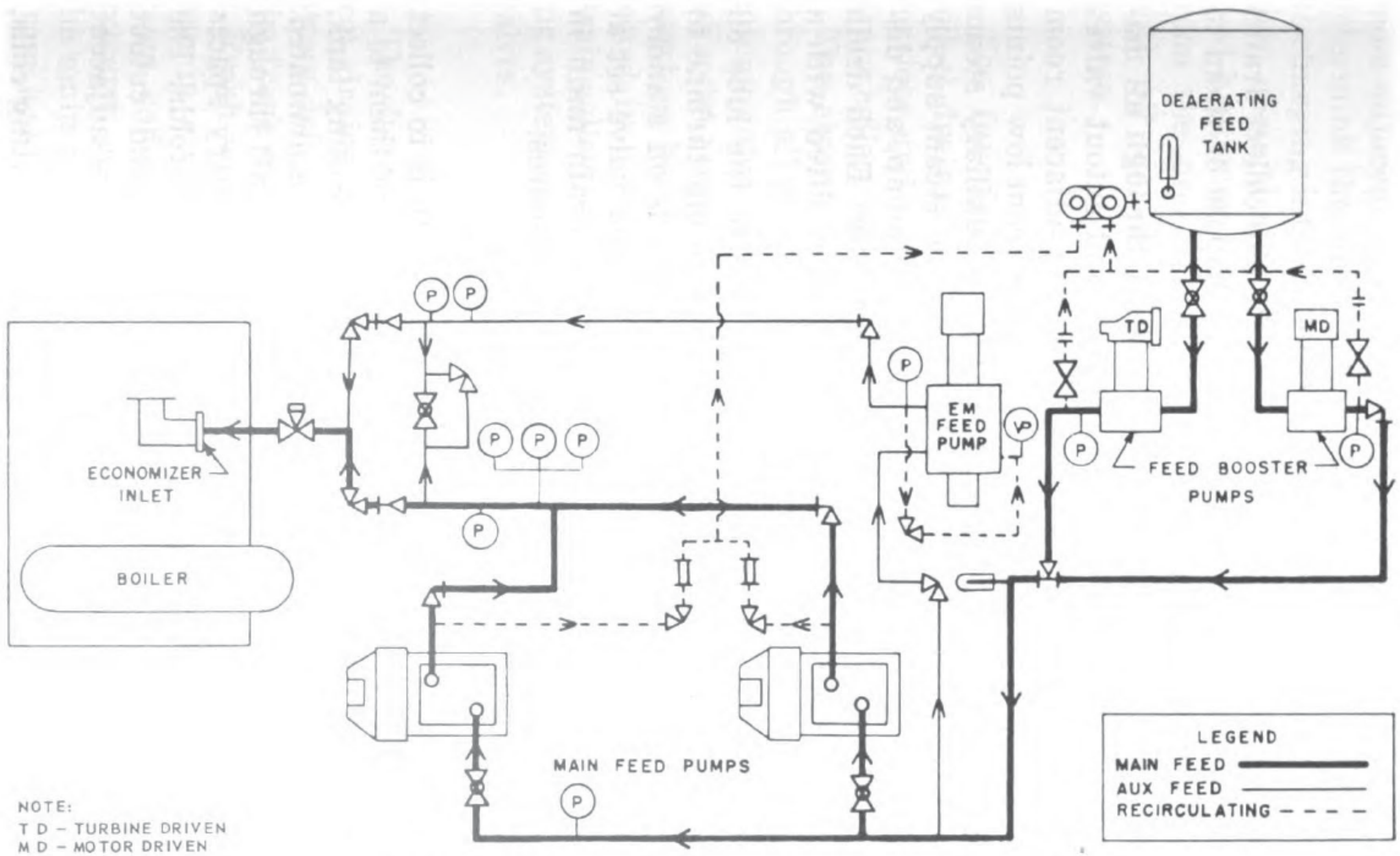


Figure 2–13.—Feed water piping circuit on a CA 139 class vessel.

3. Steam heating drain main.
4. Fresh water drain main.
5. Waste water drain main.

Steam Drain Main

The function of the steam drain main is to collect drains from high-pressure steam piping and dispose of them to the deaerating feed heaters.

The steam drain extends fore and aft through all machinery rooms and is fitted with bulkhead cutout valves which are operable locally and from the adjacent room (fig. 2–14). This main collects all drains from low points of the main steam, 600 psi and 150 psi auxiliary steam systems, the superheater headers, and the steam supply line to the turbine-driven lube oil service pump, and discharges them to the deaerating feed heater. Each drain line connected to the steam drain main is fitted with a strainer and an impulse trap.

The drain from the steam supply line to the lube oil service pump assures dry steam to the pump turbine to permit instant starting up when this unit is on standby duty and the operating pump fails. A relief valve set at 75 psi protects the section of the steam drain main in each machinery room against excessive pressures.

Oil Heating Drain Main

The function of the oil heating drain main is to collect drains from oil heating services and dispose of them to a deaerating feed tank or fresh water drain collecting tank, if clean, or to a waste water drain tank, if contaminated.

The oil heating drain main extends fore and aft through all main machinery rooms and to all machinery spaces which contain fuel oil tank heating drain manifolds. The oil heating drain main is fitted with bulkhead cutout valves which are operable locally and from the adjacent room. (See figure 2–14.)

Drains from fuel oil heaters, fuel oil tank heating coils, and lubricating oil settling tank heating coils are col-

lected in the main which discharges through an inspection fitting. This fitting is installed in each machinery room adjacent to the deaerating feed tank, and is used to determine the condition of the oil heating drains before discharging into the deaerating feed tank. After examination, clean drains may be discharged to the deaerating feed heater or to the fresh water drain tank, depending upon the pressure of the drains. Drains contaminated with oil may be discharged to the waste water drain system.

Steam Heating Drain Main

The function of the steam heating drain main is to collect drains from all constant and intermittent heating services and to dispose of the drains to the fresh water drain collecting tank.

The steam heating drain main extends fore and aft through all machinery spaces and is fitted with bulkhead cutout valves which are operable locally and from the adjacent room. (See figure 2–14.) Drains from the ship's quarters heating, galleys, and laundry services are collected in a drain main which is led to the fresh water drain collecting tank. Each item of equipment in the heating system is fitted with its own trap, strainer, and cutout valves.

Fresh Water Drain Main

The function of the fresh water drain main is to collect drains from low-pressure steam piping and from steam-driven auxiliaries. The collected drains are led to the fresh water drain collecting tanks.

Fresh water drain piping forms an independent system in each machinery room. The drain main in each room collects drains from low points of the auxiliary exhaust, gland sealing, and gland exhaust systems from the main and auxiliary air ejector after-condensers, and from leakoff, steam chests, and casings of steam-driven auxiliary machinery. In addition, the fresh water drain

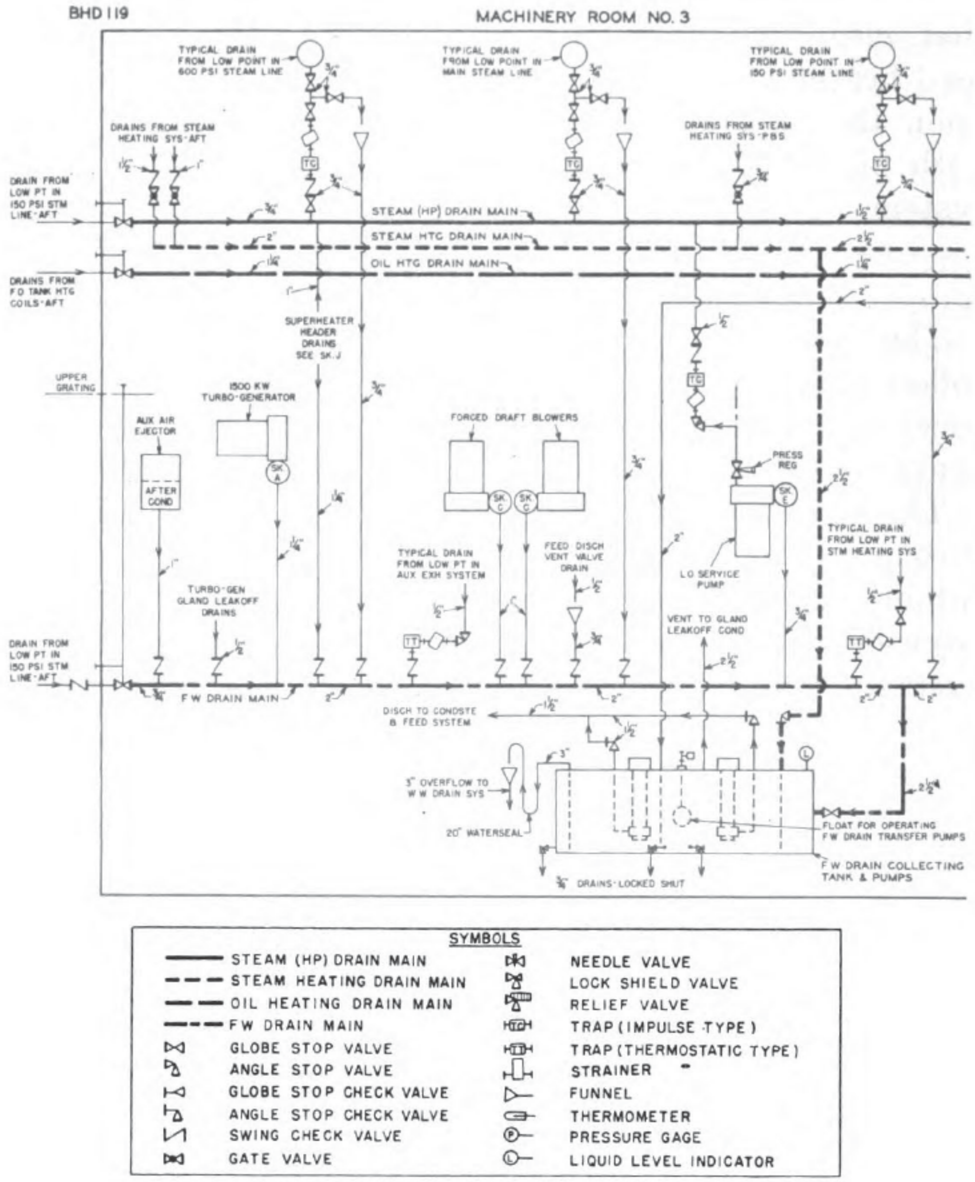
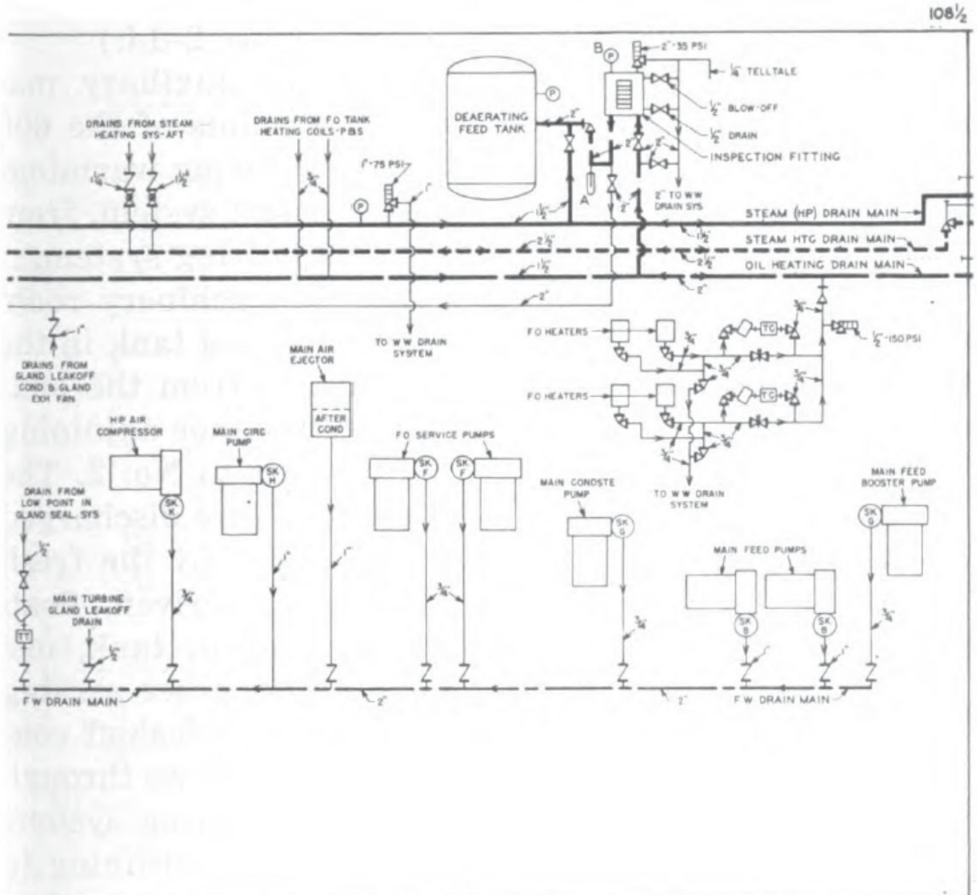


Figure 2–14.—Steam and fresh water drains of aft machinery group on CA 139 class vessels.



THERMOMETERS A EQUIPPED WITH LABEL PLATE STATING "VALVE TO DFT SHOULD BE CLOSED & VALVE TO F.W DRAIN COLL TANK SHOULD BE OPENED WHEN TEMPERATURE FALLS BELOW 250°F."

GAGES B EQUIPPED WITH LABEL PLATE STATING "VALVE TO F.W DRAIN COLL TANK TO BE OPENED WHEN PRESSURE FALLS BELOW PRESSURE IN DFT."

PIPE SIZES SHOWN FOR STEAM HEATING DRAIN MAIN APPLY TO CA134 ONLY AND WILL VARY FOR OTHER SHIPS OF THE CLASS.

Figure 2–14.—Steam and fresh water drains aft machinery group on CA 139 class vessels—Continued.

main collects drains from the main steam, 600 psi and 150 psi auxiliary steam systems during warming-up of these systems. Drains from the whistle and siren discharge to the main in machinery room No. 4, while drains from the distilling unit in machinery room No. 1 discharge to the main in that room. (See figure 2–14.)

The fresh water drain piping in the auxiliary machinery room collects drains from low points of the 600 psi and 150 psi auxiliary steam systems during warming-up, from low points of the auxiliary exhaust system, from the distilling unit, and from the steam heating system.

The fresh water drain main in each machinery room discharges to the fresh water drain collecting tank in the same room while the fresh water drains from the auxiliary machinery room may discharge to either adjoining machinery room, forward to No. 4 or aft to No. 2. The fresh water drains in each collecting tank are discharged to the condensate system in the same room by the fresh water drain transfer pumps. Two motor-driven, float-controlled transfer pumps serve each drain tank, one pump being normally in operation and the other serving as standby. Each tank is vented to the gland leakoff condenser in the same room, and each tank overflows through a water seal to the waste water drain collecting system. Locked valves are installed at each tank for draining to the bilge.

Waste Water Drain Main

The function of the waste water drain main is to collect drains subject to oil or salt water contamination and dispose of them overboard.

The waste water drain system is entirely independent in each machinery space, with a drain collecting tank installed in each machinery room to receive all contaminated drains. (See figure 2–15.) The drain tanks in machinery rooms Nos. 4, 2, and 3 are pumped out via eductors and the drainage main. The drain tanks in machinery room No. 1, and in the auxiliary machinery

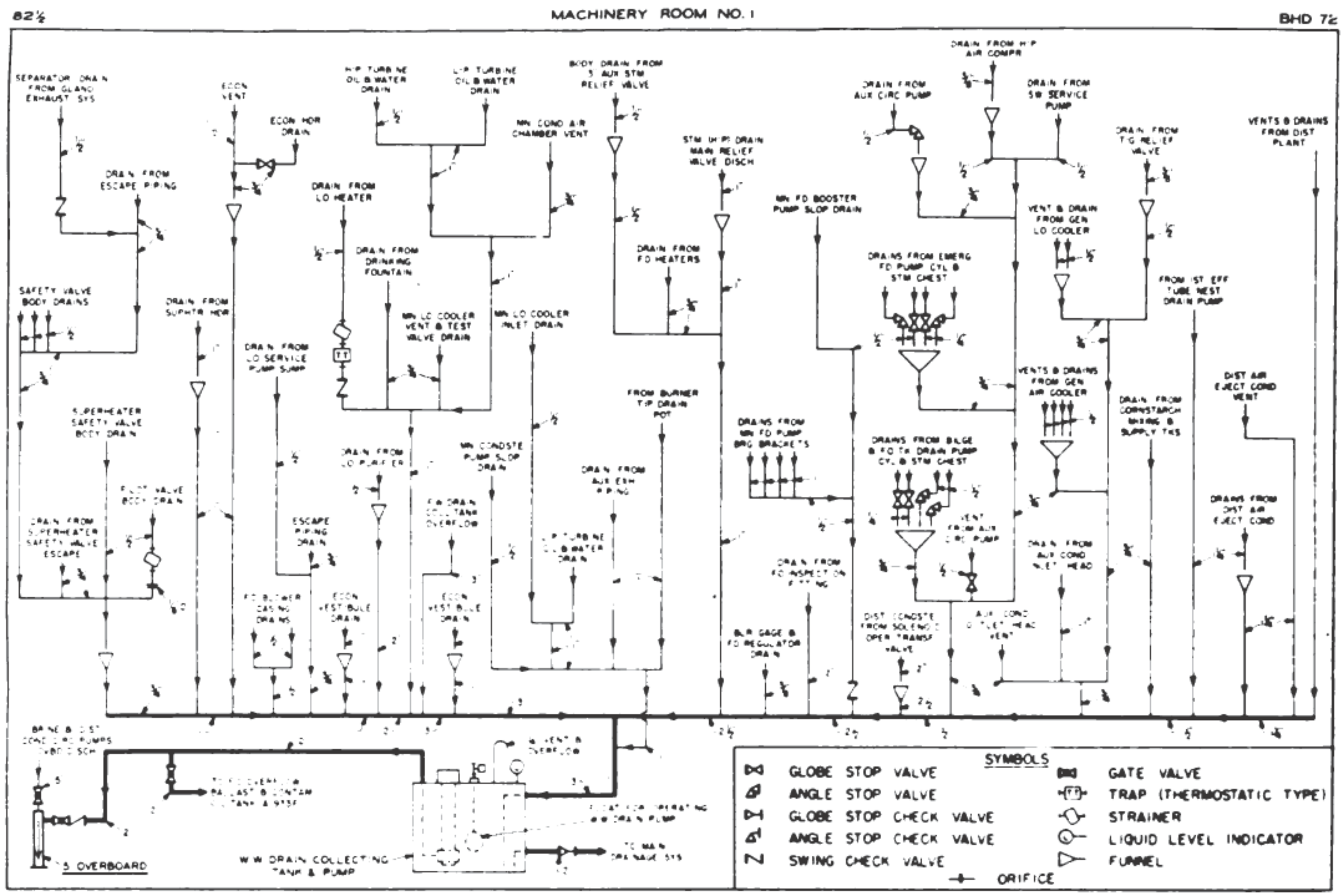
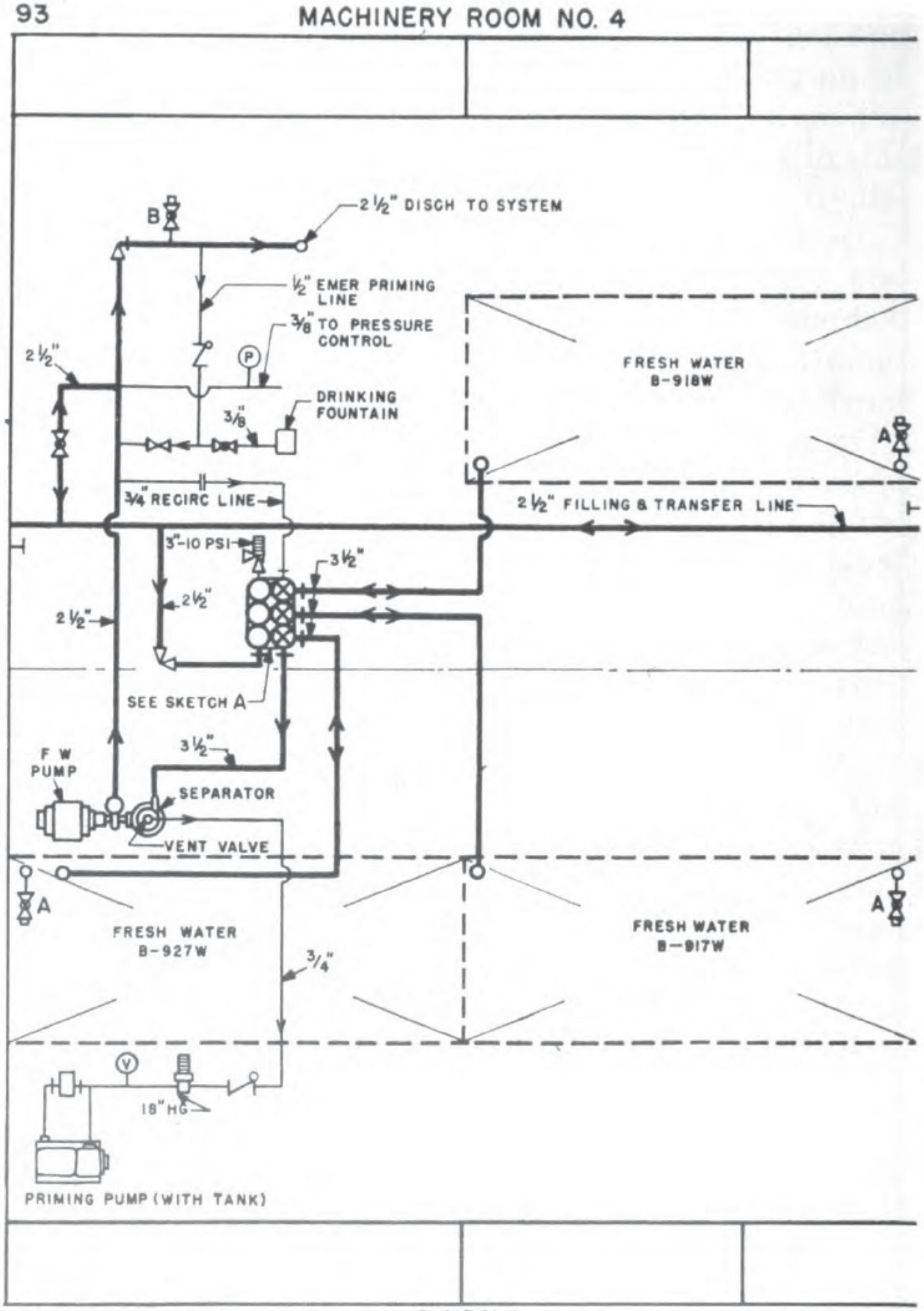


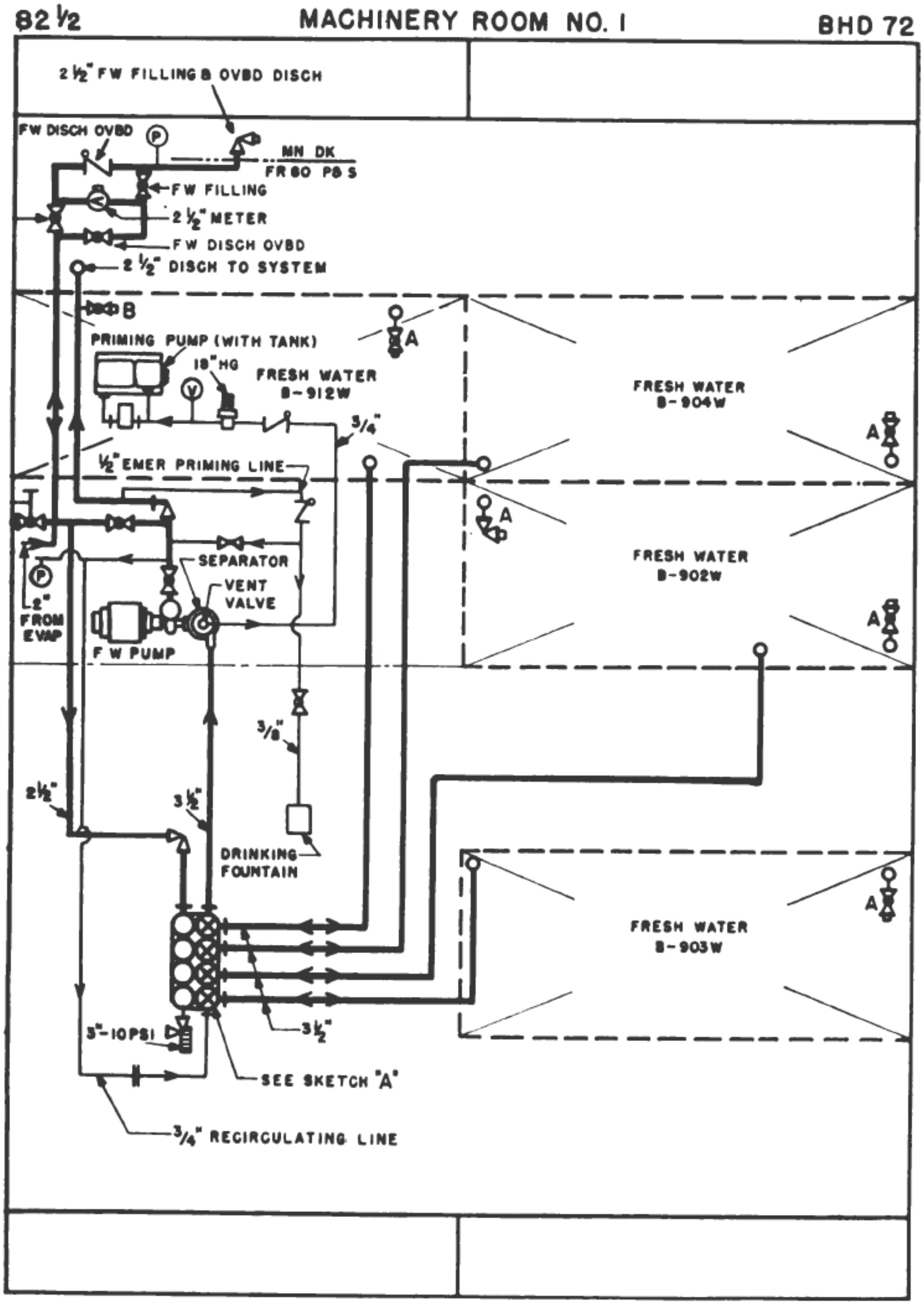
Figure 2-15.—Waste water drain main in machinery room No. 1 of a CA 139 class vessel.



SYMBOLS

	GATE VALVE		SWING CHECK VALVE		STRAINER
	GLOBE STOP VALVE		RELIEF VALVE		PRESSURE GAGE
	ANGLE STOP VALVE		ORIFICE		VACUUM GAGE
	HOSE GATE VALVE		STOP VALVE MANIFOLD		STOP CHECK VALVE MANIFOLD
	STOP CHECK VALVE		VACUUM RELIEF VALVE		

Figure 2–16.—Fresh water system of a CA 139 class vessel showing machinery rooms Nos. 1 and 4.



VALVES A HAVE 1 1/2" HOSE CONNECTIONS TO DRAINAGE SYSTEM FOR DRAINING F W TANKS
VALVES B HAVE 1 1/2" HOSE CONNECTIONS FOR FLUSHING F W TANKS.

Figure 2–16.—Fresh water system of a CA 139 class vessel showing machinery rooms Nos. 1 and 4—Continued.

room are fitted with float-actuated waste water drain pumps. These drain pumps automatically discharge overboard high salinity distillate from the distilling units located in these rooms.

In addition to its discharge overboard, the waste water drain pump in machinery room No. 1 also has a discharge connection to an adjacent contaminated oil tank. This connection serves when in port, so that oily drains may be discharged to this tank rather than overboard. All overboard discharge lines are fitted with a check valve to prevent accidental flooding of the drain tanks from the sea.

FRESH WATER

The fresh water system is designed to provide a constant supply of fresh water to all ship's service requirements, and to supply fresh water to shore or to another ship.

The fresh water system is arranged in the form of a transfer and filling main which runs through machinery rooms Nos. 1, 4, and 2, and through the auxiliary machinery room. The main deck filling and discharge connections, both port and starboard, connect to this main in machinery room No. 1. In addition, two connections from the distilling units are provided, one in machinery room No. 1 and the other in the auxiliary machinery room. Bulkhead-located cutout valves are operable locally and from the adjacent room. These cutout valves permit isolating sections of the fresh water system. A branch line from this main to the filling side of the fresh water manifold in each room permits a tank to be filled from the transfer and filling main. In machinery room No. 1, a valve is provided in the fresh water pump discharge to permit isolation of the unit while the system is being supplied from the deck. (See figure 2–16.)

Fresh water for all ship's service requirements is supplied by four fresh water pumps located in machinery

rooms Nos. 1, 4, and 2, and in the auxiliary machinery room. All pumps are motor driven, centrifugal units, and have a capacity of 125 gallons per minute (gpm) at 60 psi total head. Each fresh water pump can take suction from any tank of its group and discharge to the following:

1. To the second deck transfer main via the riser in the same room or via the machinery room transfer main and a riser in another room.
2. To the deck connections for pumping to another ship or to shore.
3. To any other fresh water tank in the same group through the manifold in the same room.
4. To any other fresh water tank through the transfer and filling main.

The filling and discharge line is provided with a meter for determining the amount of fresh water taken aboard or discharged overboard.

A hose valve is provided in the discharge of each fresh water pump to permit flushing a fresh water tank by means of a hose discharging through a tank manhole. A hose valve on the sounding tube of each tank permits the flushing water to be removed by means of a hose connected to a hose valve on the drainage main. The flushing and draining valves are marked A and B respectively in figure 2–16.

SALT WATER SYSTEMS

The salt water systems (fig. 2–17) in machinery spaces may be divided into the following groups:

1. Circulating water for main condensers and for main lube oil coolers.
2. Circulating water for auxiliary condensers and for turbogenerator lube oil and air coolers.
3. Salt water service main for auxiliary lube oil coolers and for miscellaneous cooling services.
4. Fire and flushing system.
5. Main drainage system.

For purposes of clarity, each of these groups is presented separately in the following sections, with cross references where the groups become interdependent.

Circulating Water-Main Condenser

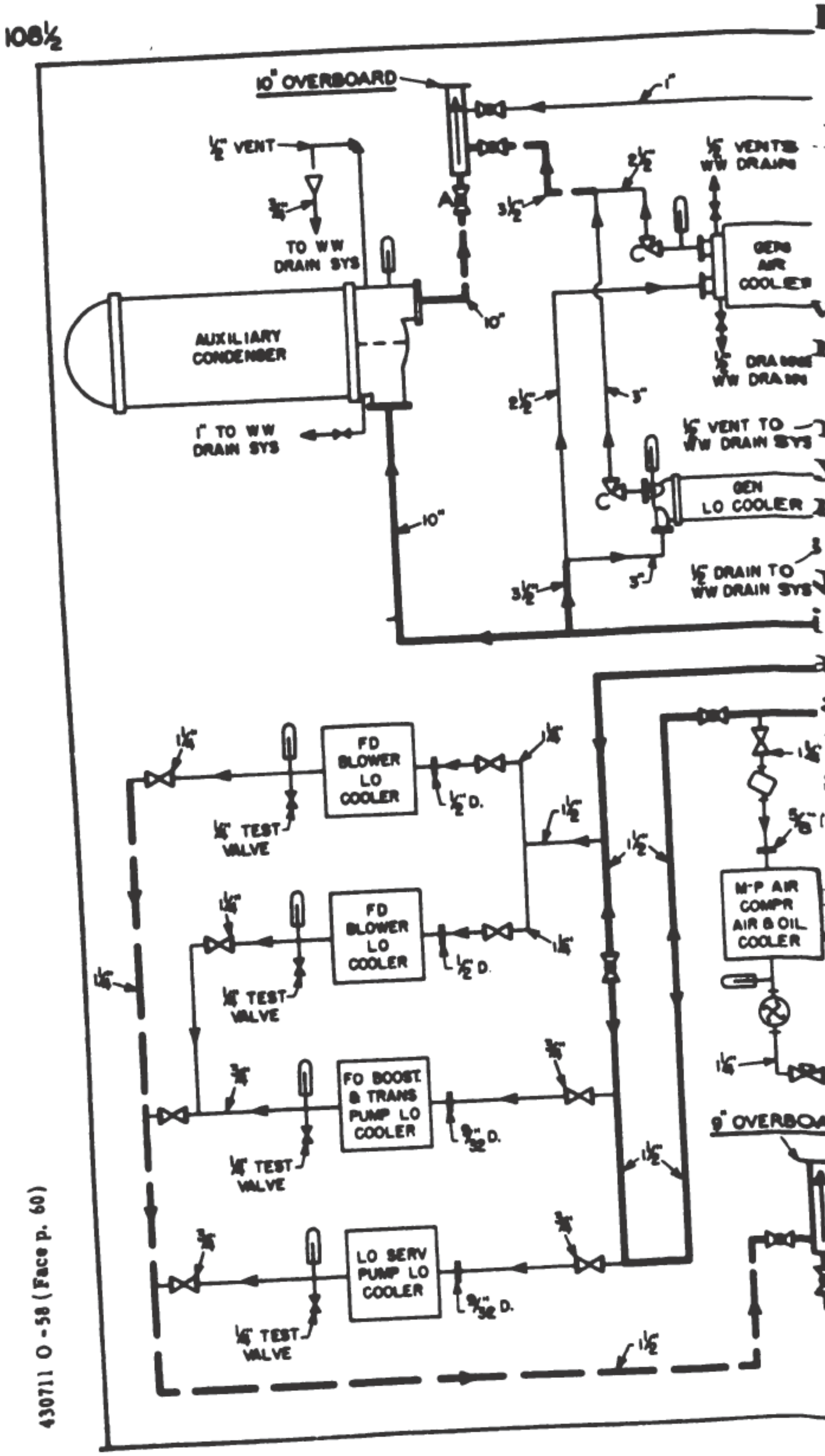
The function of this system is to supply cooling water to the main condenser and to the main lube oil cooler. Two sources of circulating water are provided at the inlet of each main condenser, one via a 32-inch line from the main injection scoop, the other via a 26-inch line from the main circulating pump. A gate valve is provided at each sea chest and is operable from the upper grating. Divided island type check valves are installed in each of these lines to prevent the short circuiting of circulating water. Circulating water is led overboard from each main condenser via a 36-inch overboard discharge line.

A 9-inch line is led from the inlet head of each main condenser to the associated main lube oil cooler. A gate valve in this line is operable from the turbine operating platform. A $\frac{1}{2}$-inch hose valve is installed in this line to receive auxiliary exhaust steam via temporary $\frac{3}{4}$-inch hose for heating the lube oil, when necessary, prior to starting a main propulsion unit. The discharge from the cooler is led to its own overboard sea chest. Cooling water for the lube oil cooler of the main circulating pump is taken from the pump discharge and returned to the pump suction.

A vent header is installed in the inlet head of the main condenser, and is connected to the outlet head by a 2-inch line. An air chamber is installed in a vertical position above the condenser. A $\frac{1}{2}$-inch valved line to a bilge funnel drain is located on the air chamber. This valve should be opened periodically, and should remain open until a full flow of water is discharged. The full flow indicates that all air has been vented from the inlet header.

A $1\frac{1}{2}$-inch hose valve is located at the lowest point of the inlet and outlet heads of the main condenser. These valves are used for draining the condenser by gravity, or

108½



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pumping out the condenser through temporary 1½-inch hose connected to the suction of the bilge and fuel oil tank drain pump.

The arrangement of this system is similar in all main machinery rooms, and is shown diagrammatically in figure 2–17.

Circulating Water-Auxiliary Condenser

The function of this system is to supply cooling water to the auxiliary condenser and to the lube oil cooler and air cooler for the turbogenerator.

Circulating water is supplied to this system by a motor-driven auxiliary circulating pump located directly beneath the auxiliary condenser. This pump takes suction via a 12-inch injection sea chest in machinery rooms Nos. 1 and 3, and a 14-inch chest in machinery rooms Nos. 2 and 4. The auxiliary circulating pump discharges via the auxiliary condenser, the lube oil and air coolers, and a 10-inch overboard discharge sea chest. A high-lift angle stop valve is installed at the injection sea chest and is operable from the generator operating level, as is the gate valve in the discharge line from the condenser. The supply to the generator lube oil and air coolers is obtained from the pump discharge via a separate line which divides to supply each of the coolers individually. A locally-operated high-lift angle stop valve is provided at each cooler outlet and is used for regulation of the circulating water flow through these units. The two outlet lines are combined into one overboard discharge line and led to the same overboard sea chest as the auxiliary condenser. A gate valve is located at the sea chest.

A 2-inch relief valve set at 20 psi protects the circulating water system and condenser waterside from excessive pressures.

The arrangement of this system is similar in all main machinery rooms, and is shown diagrammatically in figure 2–17.

Salt Water Service

The salt water service system supplies salt water to auxiliaries and miscellaneous services requiring relatively small amounts of cooling water.

An independent salt water service system is provided in each main machinery room. A motor-driven, centrifugal salt water service pump is installed in each machinery room to supply the system of that room with sea water. A duplex strainer in the pump discharge assures that this normal source of water will be free of foreign matter which might clog or damage the valves, orifices, or coolers of the system. In addition, sea water may be discharged to the system in each room from the section of firemain in the same room via a 2-inch, 150- to 30-psi reducing valve. A relief valve set at 35 psi is provided at the reducing valve outlet. (See fig. 2–17.)

A rotary flow indicator and an automatic shut-down valve are provided in the cooling water system for each high-pressure and medium-pressure air compressor. The flow indicator gives visible evidence that cooling water is being circulated through the unit. The automatic valve shuts down the unit if the flow of cooling water fails, and also shuts off the cooling water when the unit is not running.

Cooling and flushing water is continuously available at each stern tube stuffing box when under way. The stuffing boxes for No. 1 and No. 4 stern tubes are supplied from the salt water system in machinery room No. 3. An orifice is provided in each supply line to limit the maximum flow. A stop valve is installed at the stuffing box and is wide open for flushing and partially open whenever the normal supply from the sea is insufficient. No. 2 and No. 3 stern tube stuffing boxes are supplied from the firemain in the aft diesel generator room. The piping arrangement to these stuffing boxes is similar to that for No. 1 and No. 4 stern tubes, and the cooling and flushing operations are the same.

A salt water service system is also provided in the auxiliary machinery room. The only source of sea water to this system is from the firemain in that room via a 1-inch 150- to 30-psi reducing valve. Since this reducing valve is the only source, a duplex strainer is installed at the inlet to minimize the possibility of damage to the valve. A relief valve set at 35 psi protects the system from excessive pressure should the reducing valve become deranged.

In each main machinery room, the salt water system supplies circulating water to the individual lube oil coolers provided for the turbine-driven units, and to the air coolers for the compressors. An orifice at the inlet to each unit limits the flow to the amount necessary for adequate cooling. A thermometer is provided at the outlet from each auxiliary cooler, and is used in conjunction with the oil or air temperatures of the unit as an indication of sufficient salt water flow. An inlet and an outlet valve are provided at each cooler and the flow through the unit is normally regulated by the inlet valve. A vent valve is also provided at each cooler to rid the system of entrapped air.

A ¾-inch hose connection is provided for each main propulsion shafting spring bearing. These connections are provided in the salt water system of each room containing spring bearings, and are located conveniently near the bearing to be supplied. For the spring bearings in the after diesel generator room the hose connections are provided in the firemain in that room. In the event of excessive overheating of a bearing, and continued operation is required, sufficient cooling may be obtained by spraying water on the bearing from the temporary hose.

Fire and Flushing System

The principal function of this system is to supply water to all fire fighting services throughout the ship. Secondary functions include the supply of water to the flushing system, the salt water service system, the gasoline system,

the fuel oil tank ballasting system, the drainage system eductors, the Freon condensers, and the water injectors for three-inch 50-caliber twin-gun mounts.

The arrangement of the fire and flushing mains, one port and one starboard, extend the full length of the machinery spaces. One athwartship main, connecting the two fore-and-aft mains, is provided in each machinery room. All supplies to, and services from, the system are connected to the athwartship main. Valves are provided in the fore-and-aft mains to permit isolation of each machinery room, and may be manually-operated locally, or hydraulically operated, with exceptions, from the second deck. The two exceptions are the cutout valves in the fore-and-aft mains at the aft bulkhead of the auxiliary

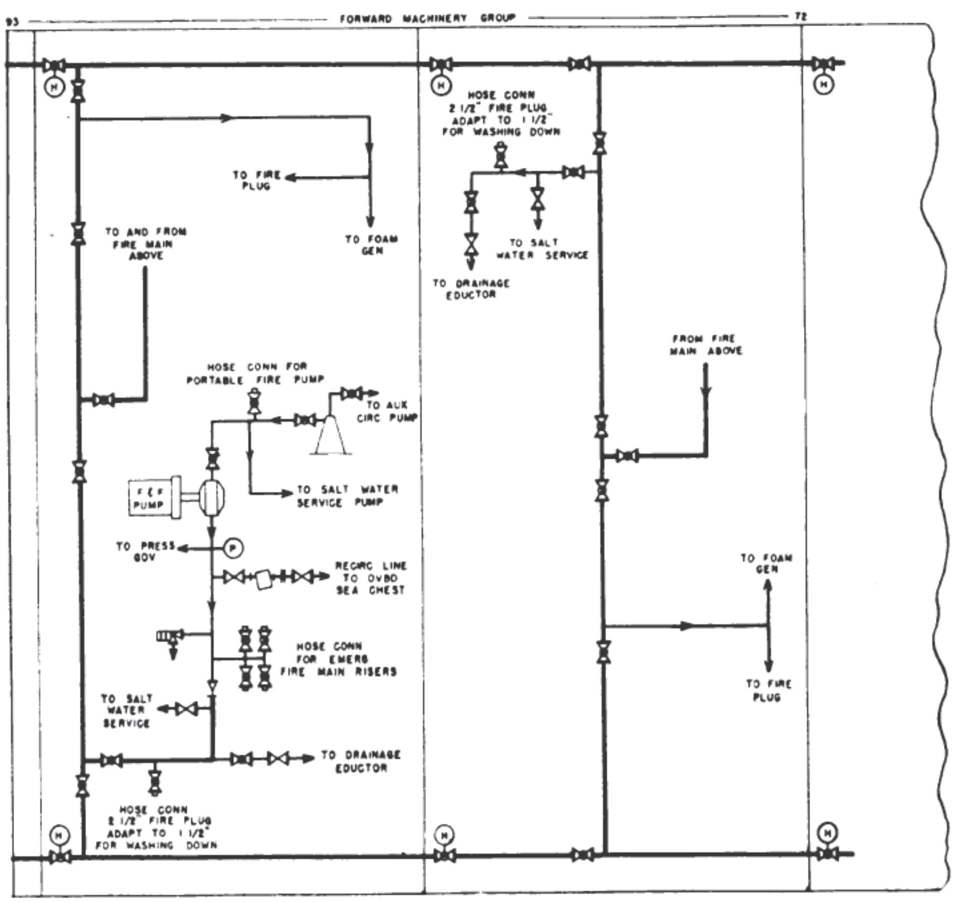


Figure 2–18.—Fire and flushing system in machinery rooms of a CA 139 class vessel.

machinery room and the aft bulkhead of machinery room No. 2. These cutout valves may be operated only locally. Thus, when isolating by remote hydraulic control, the firemain in the auxiliary machinery room and in machinery room No. 2 remains a single unit. Additional valves are provided in the fore-and-aft mains to permit further subdivision of these mains within a machinery space, and may be operated only locally. Valves in each athwartship main permit the isolation of each connection to this main, and may be operated only locally. This arrangement is partially shown in figure 2–17. However, figure 2–18 shows the diagrammatic arrangement, including supplies to and from the fire and flushing system.

Water may be supplied to this system from any fire

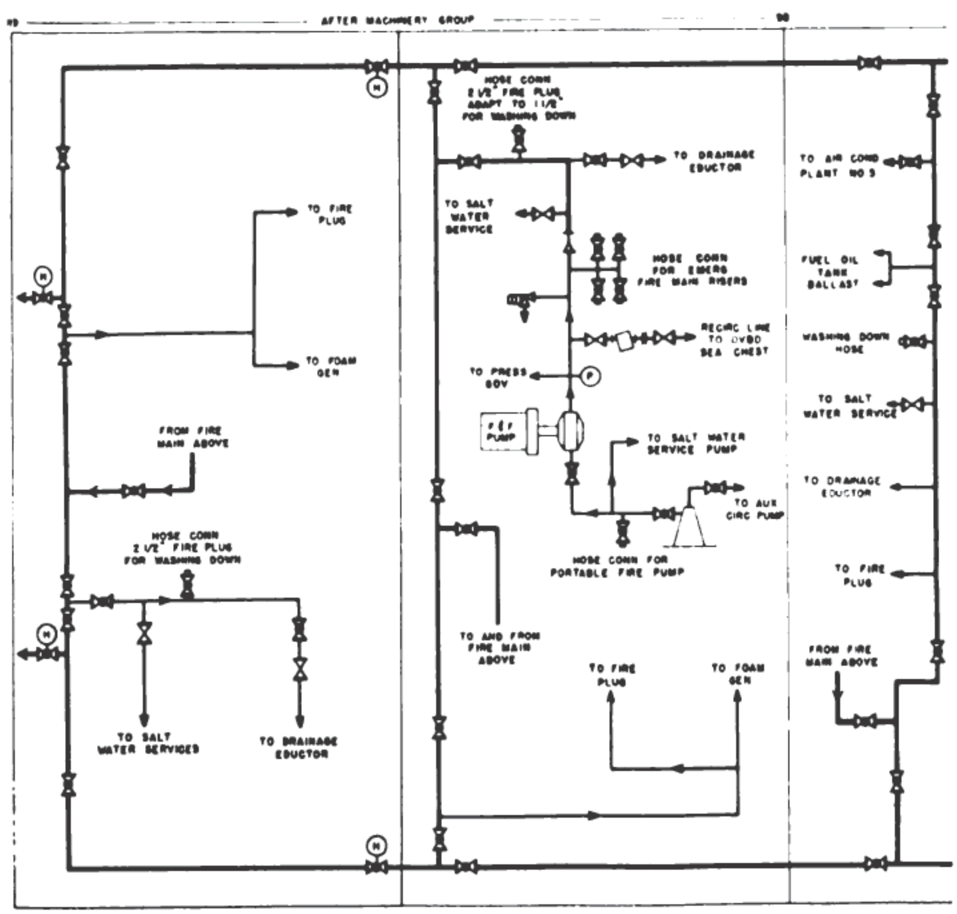


Figure 2–18.—Fire and flushing system in machinery rooms of a CA 139 class vessel—Continued.

and flushing pump on the vessel. There are seven such pumps; three are in the hold, No. 1 pump, a 500 gpm, is motor-driven; No. 2 pump, a 1000 gpm, is motor-driven; and No. 3 pump, a 1000 gpm, is also motor-driven; No. 4 is a 1000 gpm, turbine-driven pump and is in machinery room No. 4; No. 5 is a 1000 gpm, turbine-driven pump and is in machinery room No. 2; No. 6 is a 1000 gpm, motor-driven pump and is in the after emergency diesel room; and No. 7 is a 500 gpm, motor-driven pump and is on the platform deck.

The motor-driven pumps are constant-speed units with start-and-stop control both locally and from a remote station. The turbine-driven pumps operate under control of a constant-pressure regulator which is set to maintain constant pump discharge pressure at varying system demands. All pumps are fitted with recirculating lines from the pump discharge to an overboard sea chest, other than the pump suction sea chest. A valve is provided at the pump and at the sea chest, and an orifice is installed to limit the flow to an amount necessary for pump cooling.

In the machinery spaces, water may be supplied from the fire and flushing system to the following services in each machinery room:

1. Hose plug in each room adjacent to a hose rack.
2. Foam generator.
3. Drainage eductor.
4. Salt water service system.
5. Hose connection for washing down purposes.

In machinery rooms Nos. 2 and 4, a manifold of four 2½-inch hose connections is installed at the discharge of the turbine-driven fire and flushing pump. In the event of loss of the firemain riser from either of these rooms, emergency risers made up of temporary hose may be fitted from these connections to spaces outside the machinery room. Similar hose connections, one for every 250 gpm of pump capacity, are provided at each fire and flushing pump on the vessel.

Also, for emergency use, a 3½-inch hose connection is

provided near each auxiliary injection sea chest in each machinery room. A portable fire pump may be connected, via a 4-inch temporary hose to this fitting, to take suction from the sea and discharge to the system through a temporary hose connected from the pump discharge to any convenient system hose connection.

A $2\frac{1}{2}$-inch hose connection is also installed in the riser from the firemain in each machinery room and may be used for emergency fire hose supply. A $1\frac{1}{2}$-inch adapter is provided for this hose connection to permit the use of smaller hose for washing down purposes.

In the after emergency diesel generator room, the fire and flushing system supplies cooling water to the stern tube stuffing boxes for shafts No. 2 and No. 3, and also supplies, via a temporary hose, cooling water to the spring bearings in that space.

Main Drainage

The function of the main drainage system is to remove any water which may reach the bilges of void or working spaces in the main machinery rooms, the diesel generator rooms, the fuel oil pump rooms, or in the turrets.

The main drainage system extends the full length of the armored portion of the vessel, and is divided into four independent, unconnected sections (fig. 2–19).

The forward section receives all the drains from No. 1 turret and from the forward fuel oil pump room, and leads them to a common drain well located in the pump room. The valves in the combined drain lines from the turret are operable from within the turret and from the fuel oil pump room. Either of two eductors located in the pump room may take suction from the drain well and discharge overboard. The power water for the eductors is obtained from the fire main in that section of the ship.

The second section receives all the drains from No. 2 turret and leads them to a drain main extending from the forward 1000 gpm fire pump room to the pump and compressor room. This main has suction connections to three

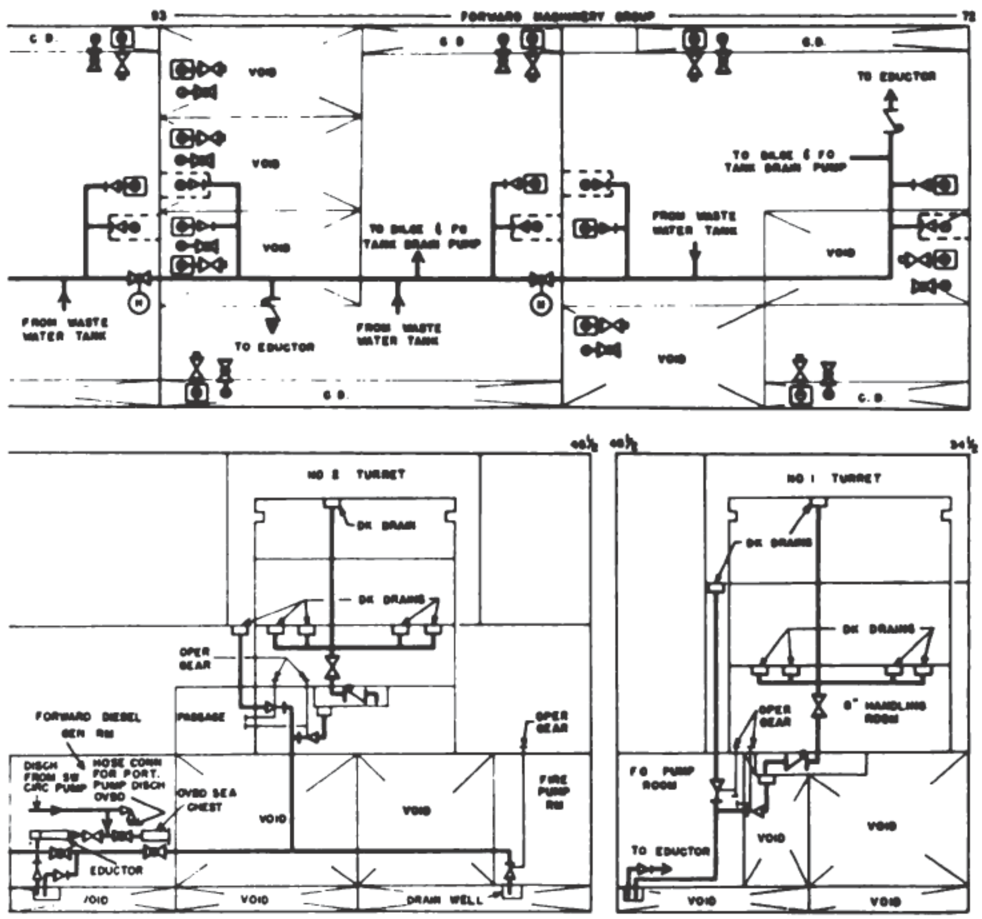


Figure 2-19.—Main drainage system of a CA 139 class vessel.

drain wells, one in the forward 1000 gpm fire pump room, one in the forward diesel generator room, and one in the pump and compressor room. Either of two eductors located in the pump and compressor room, may take suction directly from the main and discharge overboard. Again, power water to the eductors is obtained from the firemain in that area. A stop-check valve is installed at each drain well and extension stems are provided to permit operation of the valves from the deck above. Stop valves are installed in the main to permit isolation of sections of the main in the event of damage. These valves are located in the diesel generator room. The valves in the combined drains from the turret are operable from within the turret and also from the passageway on the second platform. A second method of drainage for emer-

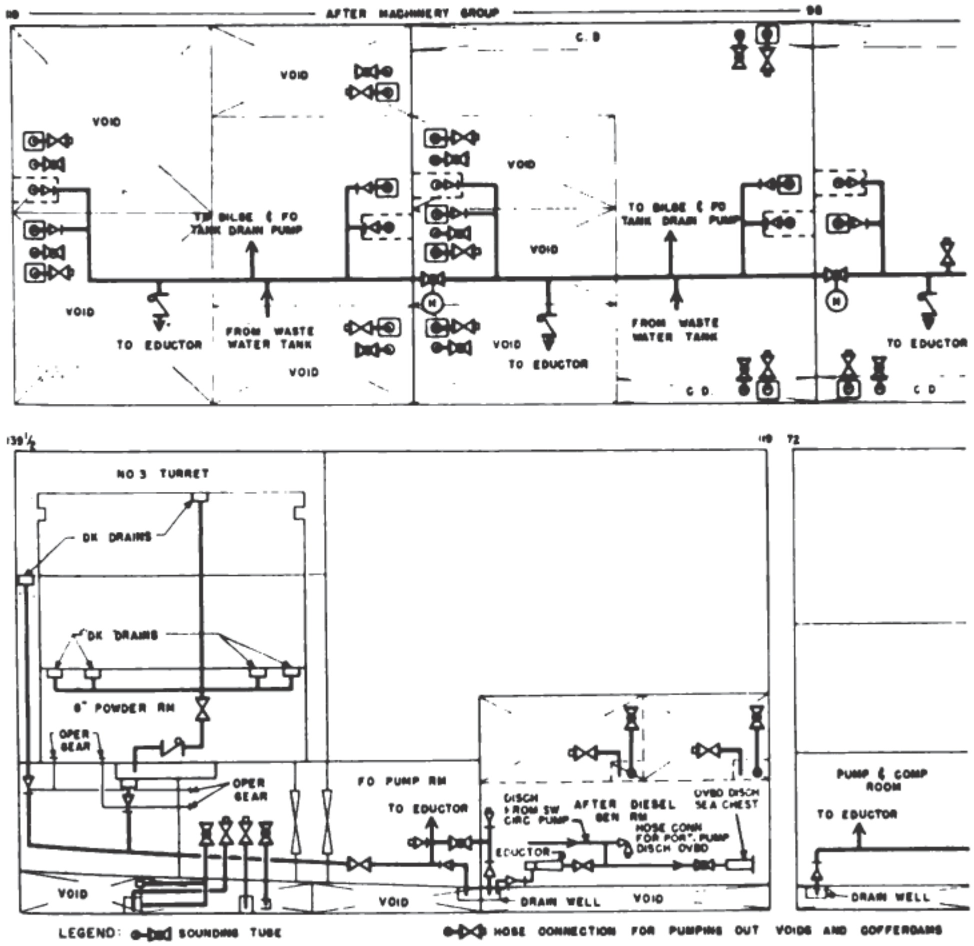


Figure 2-19.—Main drainage system of a CA 139 class vessel—Continued.

gency use in the diesel generator room is provided by the installation of an eductor in that room. This eductor takes suction from the same drain well and discharges overboard via the discharge line from the salt water circulating pump attached to the diesel engine. A third method of drainage in the diesel generator room, for emergency use, is provided by a portable submersible pump. This unit takes suction from the drain well and discharges overboard via temporary hose and the connection installed on the salt water circulating pump overboard discharge.

The two emergency methods of drainage just described are only intended for use when the main drainage line is carried away and it is necessary to maintain the diesel generator in operation.

The third section of the main drainage system extends from machinery room No. 1 to machinery room No. 3, and serves all the main machinery rooms and the auxiliary machinery room. This main is continuous through all the spaces, but may be isolated and operated independently within any one space. Cutout valves are provided at each bulkhead, and may be manually operated locally or hydraulically operated from the second deck. Two bilge wells are provided in each machinery space, one forward and one aft. A 2½-inch line is led from each bilge well to the drainage main, and a 5-inch line, located adjacent to the smaller line, is led from the inner bottom to the drainage main. Stop-check valves are provided in these lines at each well, and are operable from both the lower and upper level gratings. An eductor and a reciprocating bilge pump are connected to the drainage main in each main machinery room, and either unit may be used to discharge drainage overboard. Hose connections are provided to voids and cofferdams in each room and are connected by temporary 1½-inch hose to the hose connection at the bilge pump suction. Sounding tubes, located adjacent to the hose connections, are used as an indication of leakage in the void spaces.

In the auxiliary machinery room, only an eductor is provided for drainage removal. Therefore, in this room, a 1½-inch hose connection is fitted to the drainage main to allow for removal of leakage in the void spaces. The waste water drain system is discharged to the drainage main in each machinery space including the auxiliary room, via a stop-check valve at the waste water drain collecting tank. To remove waste water from a tank, the section of drainage main connected to it must be in service. An emergency means of drainage or leakage removal, provided in each main machinery room, is the main circulating pump bilge injection. This unit is only used in the event of serious flooding that would exceed the capacity of the drainage main. Under these conditions, the main circulating pump injection must be closed.

The after section of the main drainage system receives the drains from No. 3 turret, and leads them to a drain main connected between the after diesel generator room and the after fuel oil pump room. A drain well is located in each of these rooms, and may be connected to or isolated from the main by stop-check valves. Two eductors are provided in the pump room, and either may take suction from the main and discharge overboard. A hose connection is fitted to the main in each room to receive drainage from the void spaces. Additional drainage provisions, similar to those for the forward diesel generator room, are located in the after diesel generator room.

OTHER ENGINEERING SYSTEMS

Other engineering systems, discussed in full in succeeding chapters, include the refrigeration system and plant, the ventilation system, the mechanical cooling system, the heating system, the compressed air system and plant, the distilling system and plant, and the steering system.

MACHINERY DISTRIBUTION AND ARRANGEMENT

The design, size, quantity, arrangement, and distribution of the various main and auxiliary engineering machinery units aboard ship differ somewhat for each type and class of naval vessel. Shipboard arrangement of machinery also varies with each type and class of vessel. However, the following considerations usually determine the arrangement of machinery:

1. Simplest efficient piping arrangement.
2. Minimum weight and weight distribution.
3. Methods of machinery support.
4. Access to units for operation and repair.
5. Adequate separation and duplication of machinery for maximum resistance to damage by collision or enemy action.

Shipboard Distribution of Engineering Machinery

From about ONE-FIFTH to ONE-FOURTH of a combatant ship's space is usually devoted to engineering material. This includes space for fuel and water, main engines, boilers, evaporators, ice machines, air compressors, electricity generators, anchor engines, elevator mechanisms, steering engines, etc., and their auxiliaries.

The propulsion plant machinery (including main engines, boilers, and their auxiliaries) on nearly all naval vessels except oil tankers and landing ships, is located amidships. On the tankers and landing craft, all this main propulsion machinery is aft. Other machinery units may be located at any of a number of locations, depending upon the design of the ship. On combatant ships other than destroyers and destroyer escorts, the main machinery areas are usually protected from overhead by armored decks, and on the sides by armored steel plating. Engineering plants on destroyers, destroyer escorts, and noncombatant ships are generally protected only by the armored side platings.

The general locations, types, and specifications of the engineering machinery can be found on the Hull and Machinery Data Sheet, in each ship's *Booklet Plans of Machinery*. The locations of the machinery units with regard to the system or plant of which they are a part can be found in the ship's *Engineering Operation and Casualty Control Manual* and the instruction book on *Engineering Piping Systems*. Detailed operating data for the main propulsion plant machinery can be found in the ship's *Standard Operating Data* booklets, with which all of the latest ships are equipped.

QUIZ

1. What determines the boiling point of a liquid?
2. What is the term applied to steam which is not heated above the temperature of the water from which it is generated?
3. Where is the heat energy of shipboard boiler steam converted to mechanical energy?

4. What happens to feed water when it reaches a boiler economizer?

5. Why isn't it more practical to install all shipboard engineering machinery in one large machinery room?

6. What is the purpose of split-plant operation?

NOTE: QUESTIONS 7 THROUGH 19 ARE APPLICABLE TO CA 139 CLASS VESSELS.

7. Which of the ship's steam systems are provided with cross-connections?

8. Why are cross-connected operations utilized during peacetime conditions?

9. How is split-plant operation of the main steam system established?

10. To which three units does the main steam piping system deliver superheated steam from the boilers?

11. If the ahead throttle valve is jammed open, how can speed be controlled?

12. How can the 150 psi steam system be subdivided or extended for services fore or aft of the machinery rooms?

13. Which steam system may be used to smother an uncontrollable fire in the bilges?

14. Which steam systems are arranged in the form of a continuous loop?

15. What precaution must be taken when either supplying or receiving shore steam?

16. The auxiliary exhaust steam system supplies which machinery room units?

17. What are the operating pressure limits of the auxiliary exhaust steam system?

18. Salt water may be used for cooling purposes in which of the following units?

    (a) Main condensers.
    (b) Air ejectors.
    (c) Turbogenerator lube oil coolers.
    (d) Turbogenerator air coolers.

19. Approximately what proportion of a combatant ship's space is devoted to engineering areas?

CHAPTER 3

MAIN AND AUXILIARY TURBINES

Steam turbines are used for ship propulsion and for driving many of the auxiliary machinery units associated with the propulsion plant, such as lubricating oil pumps, condensate pumps, feed pumps, circulating pumps, fuel oil pumps, forced draft blowers, and ship's service generators.

As a Machinist's Mate 3, you will need a great deal of general information about propulsion plants and associated auxiliary machinery, and you will need specific information about the operation of the propulsion machinery installed in your ship.

In this chapter we will discuss briefly the two principal types of steam turbine propulsion plants—the geared-turbine type and the turbo-electric type. We will also discuss in detail the main and auxiliary steam turbines from the standpoint of basic design features and operating principles.

It is important to note that most of the information contained in this chapter is of a general nature only. Turbine installations vary to such an extent that it is necessary to consult the various manufacturers' instruction books for detailed information for any given unit. Further information may be obtained from the *Bureau of Ships Manual,* Chapter 41, Section I—Turbines, and Chapter 50, Auxiliary Steam Turbines.

STEAM TURBINE PROPULSION PLANTS

As mentioned earlier in this chapter, the two principal types of steam turbine ship propulsion plants in use today are the geared-turbine drive and the turbo-electric drive. The direct-drive type turbine propulsion plant, which was the forerunner of the present day plants, will be found on few, if any, naval ships.

Steam turbines must operate in a relatively high range of revolutions per minute (rpm) in order to obtain the maximum amount of work per pound of steam used. On the other hand, propellers operate most efficiently in a much lower rpm range. In the direct drive installation, neither the turbine nor the propellers could operate in their ideal rpm ranges, since both operated at identical speeds. Steam consumption, and consequently fuel consumption, in these plants was tremendously high. The need for suitable means of operating both turbine and propeller within efficient rpm ranges brought about the development of the geared-turbine drive and the turbo-electric drive.

In the geared-turbine drive, a reduction gear unit is used as the means for transforming high turbine rpm to a much lower propeller shaft rpm. In the electric drive, the necessary speed reduction is brought about electrically. That is, the turbine drives a generator at high rpm, and the generator furnishes power to drive an electric propulsion motor which operates in a low rpm range. The turbine installations in these two types of drives differ considerably, as will be pointed out in the succeeding paragraphs. However, the auxiliary machinery and equipment associated with both types of drives, such as pumps, condensers, and coolers are essentially identical as to design and operational features.

Geared-Turbine Drive

In the geared-turbine drive, the unit parts or sections which make up the individual propulsion units consist of the main turbines and the reduction gear.

Figure 3–1 shows the general arrangement of the turbines and gears in a geared-turbine propulsion unit. Not all geared turbine plants have the cruising turbine which is included in the diagram. Ordinarily, cruising turbines will be found in only the smaller ships such as frigates and destroyers.

In a typical destroyer propulsion plant, the speed reduction ratio between cruising turbine shaft and high pressure turbine shaft is approximately 1.8 to 1. The speed ratio between high pressure turbine shaft and propeller shaft is 16 to 1, and the ratio between low pressure turbine and propeller shaft is 13 to 1. In other words, in operation, if the propeller shaft is revolving at 100 rpm, the cruising turbine will be revolving at 2880 rpm (1.8 x 16 x 100), the high pressure turbine at 1600 rpm (16 x 100), and the low pressure turbine at 1300 rpm (13 x 100).

Figure 3–1 shows two astern elements, one at each end of the low pressure turbine. This arrangement is typical for combatant type ships; auxiliary type ships usually

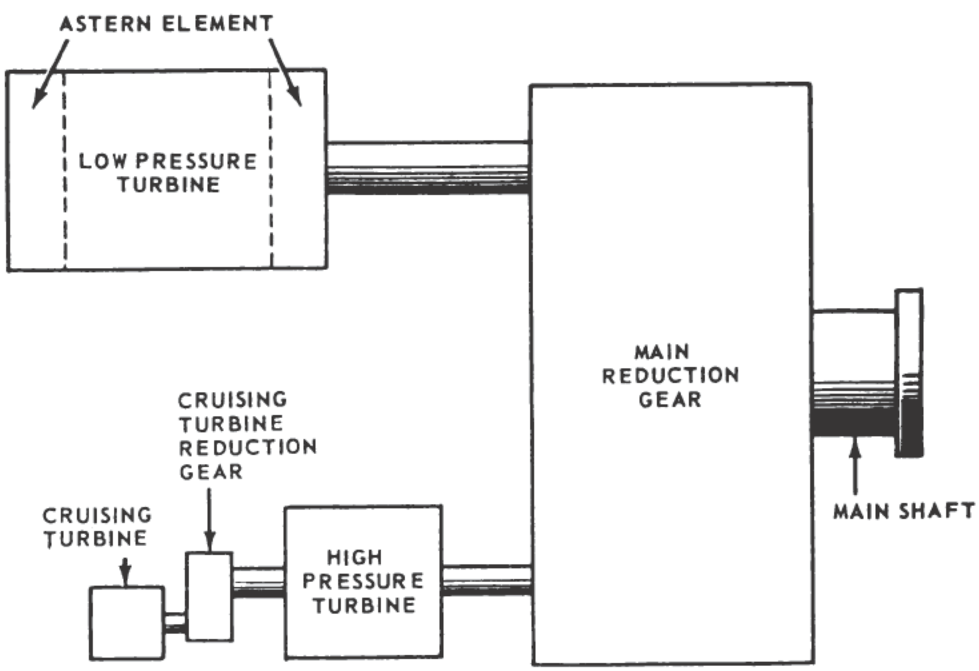


Figure 3–1.—Simple diagram of the geared-turbine propulsion unit.

have one astern element instead of two, and that one invariably is located at the forward end of the low pressure turbine (the end farthest from the reduction gear).

The PROPULSION SHAFT, which extends from the main gear (low speed) shaft of the reduction gear to the propeller, is supported and held in alignment by the SPRING BEARINGS, the STERN TUBE BEARINGS, and the STRUT BEARING. The axial thrust, acting on the propulsion shaft as a result of the pushing effect of the propeller, is absorbed in the MAIN THRUST BEARING. In most ships, the main thrust bearing is located at the forward end of the main shaft, within the reduction gear casing. In some very large ships, however, the main shaft thrust bearing is located farther aft to eliminate the "whipping" tendency that otherwise would be present when the necessarily long shaft is under heavy propulsion load. Reduction gears and bearings will be discussed in some detail in the next chapter.

Turbo-Electric Drive

Unlike geared-turbine propulsion plants, which have the two ahead turbines and an astern element for each propulsion shaft, the turbo-electric drive installations have a single turbine unit for each installed shaft. Figure 3–2 shows the diagrammatic arrangement of a turbo-electric propulsion unit. As you can see, the propulsion unit includes a turbine, main generator, propulsion motor, a direct current generator for supplying excitation current to the generator and the propulsion motor, and a propulsion control board.

The speed reduction ratio between turbine and propeller in the turbo-electric drive is approximately the same as in the geared-turbine drive and is brought about electrically. For example, in one class of turbo-electric drive type destroyer escort, the normal operating range fixed speed ratio between the turbine-generator set and the propulsion motor is 14 to 1.

One of the outstanding differences between geared

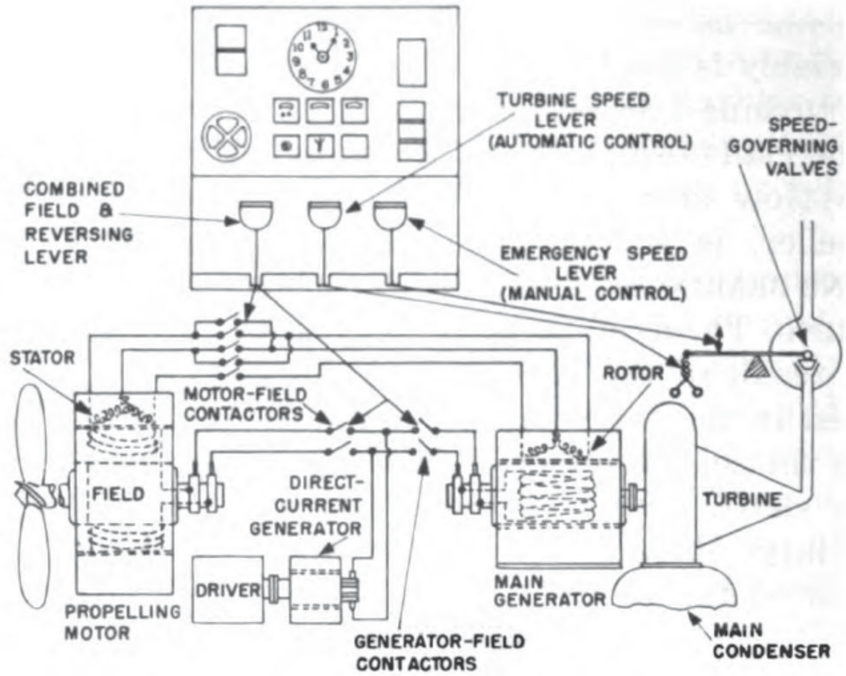


Figure 3-2.—Simple diagram of the turboelectric drive.

drive and electric drive is that the latter does not have an astern turbine element. In the electric drive, the direction of rotation of the propulsion motor, and consequently the propeller, is controlled by the electrical switch setup. Therefore, there is no need to reverse turbine rotation for astern operation.

TYPE CLASSIFICATIONS OF STEAM TURBINES

Now that you have a pretty good idea of the layout of a steam turbine propulsion plant, consider the various types of turbines that are employed—that is, turbines as a whole, those used for main propulsion power, and those used to drive auxiliary machinery.

Turbine types may be classified in four ways by the:

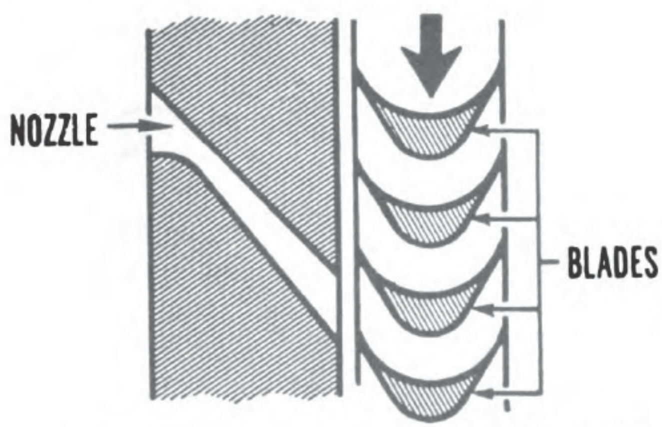
1. Manner in which the steam causes the turbine rotor to rotate.
2. Type of staging and compounding of steam pressure and velocity.
3. Division of the steam flow.
4. Direction of the steam flow.

Under each of these classifications, there are several types of turbines, some of which are described briefly in the following paragraphs. After reading these descriptions and studying the accompanying illustrations, you should be able to classify in a number of different ways every turbine used by the Navy. A fifth method of classification, repetition of steam flow (including single entry, single re-entry, and double re-entry type turbines) is also sometimes used.

CLASSIFICATION BY IMPULSE AND REACTION PRINCIPLES

The basic distinction made between turbines has to do with the manner in which the steam causes the turbine rotor to move. When the rotor is moved by a push or "impulse" from a high velocity jet of steam that strikes blades mounted on the periphery of a wheel, the turbine is said to be an IMPULSE TURBINE. When the rotor is moved by the force of reaction, the turbine is said to be a REACTION TURBINE.

The angle at which the steam hits the moving blades and the shape of the moving blades are the two main factors which determine whether the rotor is moved by a direct impulse or by reaction to an impulse. Figure 3–3 shows the nozzle and blade arrangement in an impulse turbine. Figure 3–4 shows the fixed blades and the moving blades in a reaction turbine.



Courtesy of U. S. Naval Institute

Figure 3–3.—Impulse-turbine nozzle and blades.

Impulse Turbine

In the impulse turbine, the steam expands through stationary nozzles only and so loses pressure but gains velocity. In the moving blades, the steam loses velocity but the pressure remains constant. Actually, an impulse turbine utilizes both the impulse of the steam jet and, to a lesser extent, the reactive force which results from the fact that the curving blades cause the steam to change its direction.

Reaction Turbines

In the reaction turbine, the steam enters through a row of fixed blades which expand and direct the flow of steam to the moving blades. As you can see in figure 3–4, the fixed blades and the moving blades are very similar in shape. Steam expansion takes place in both sets of blades.

A reaction turbine is moved by (1) the reactive force produced on the moving blades when the steam increases in velocity, and (2) the reactive force produced on the moving blades when the steam changes direction. However, some of the motion of the rotor is actually caused by the impact of the steam on the blades; and, to a certain extent, therefore, the reaction turbine operates on the impulse principle as well as on the reaction principle.

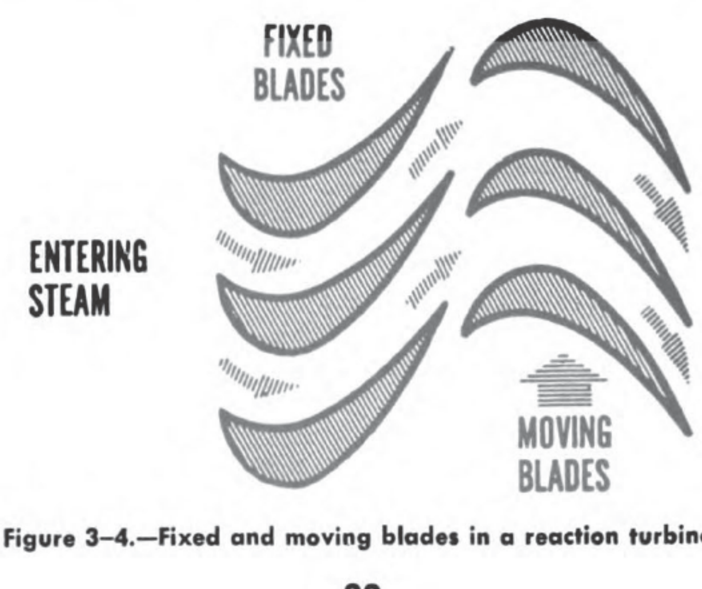


Figure 3–4.—Fixed and moving blades in a reaction turbine.

Basic Differences Between Impulse and Reaction Turbines

Now let us take time to compare the basic differences between impulse- and reaction-turbine blading. No matter what the number of fixed and moving blade rows in an impulse turbine, the pressure remains the same throughout the blading. However, the steam pressure decreases in each nozzle.

In the reaction turbine, the steam pressure decreases in every row of fixed and moving blades. There are no nozzles in the reaction turbine; the fixed blades serve the same purpose as the nozzles of an impulse turbine.

STAGING AND COMPOUNDING

In an impulse turbine, a STAGE is defined as one set of nozzles and the succeeding row or rows of moving and fixed blades. Another way of defining a stage is to say that it includes the nozzles and blading in which only one pressure drop takes place. (In an impulse turbine, remember, the only pressure drop takes place in the nozzles. Therefore, the number of sets of nozzles in an impulse turbine indicates the number of stages.)

Figure 3–5 shows a SIMPLE IMPULSE TURBINE. This turbine has one stage, consisting of one set of nozzles and one row of moving blades mounted on the rotor. Simple impulse turbines do not completely utilize the velocity of the steam, and are therefore not very efficient. They have the advantage of being simple in design and construction, however, and are often used for small auxiliary units. The simple impulse stage is usually called a RATEAU STAGE.

In the REACTION TURBINE, the steam pressure successively drops in each row of blades (whether fixed or moving). The combination of a row of fixed blades with a row of moving blades in these turbines is sometimes referred to as a DOUBLE STAGE (also known as a single REACTION STAGE).

One way to increase the efficiency of a single stage impulse turbine is to add another row (or even two more

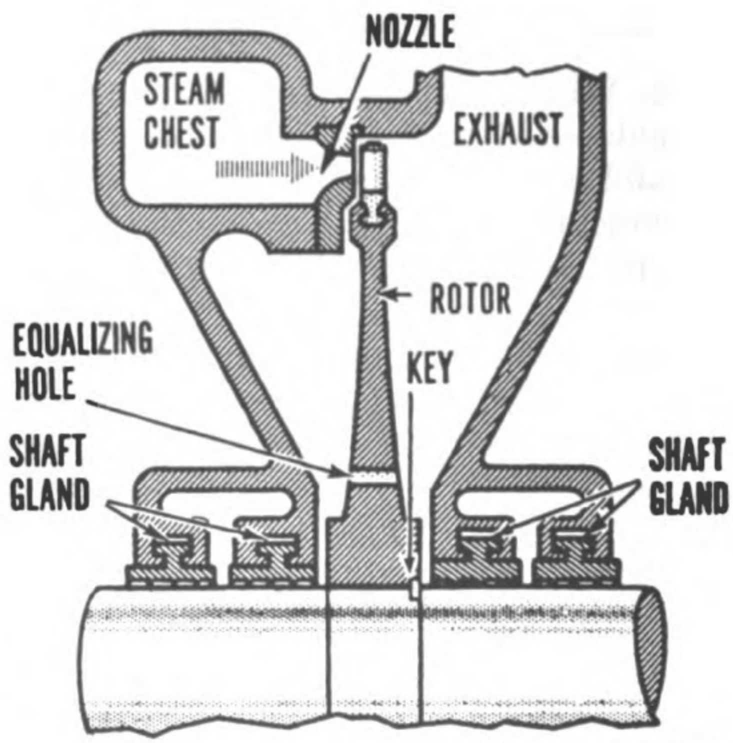


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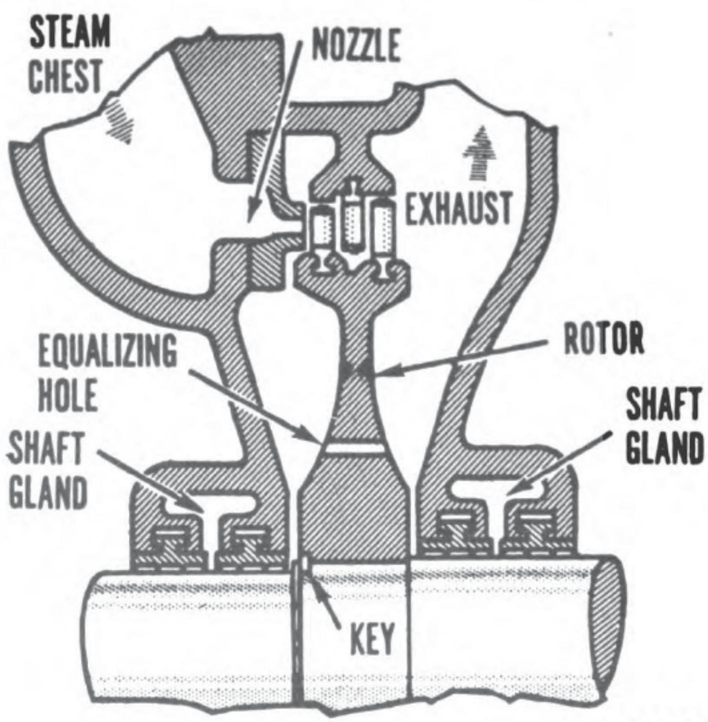
Figure 3-5.—Simple impulse turbine.



Courtesy of U. S. Naval Institute

Figure 3-6.—Velocity-compounded impulse turbine.

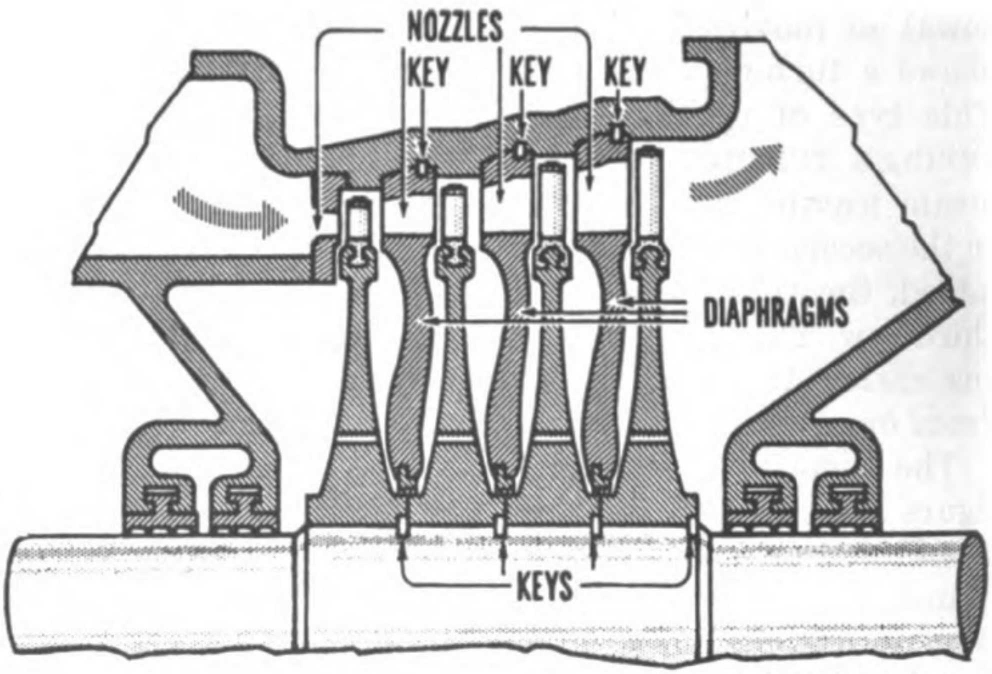
rows) of moving blades to the rotor wheel. Figure 3–6 shows a turbine which has two rows of moving blades. This type of turbine is called a VELOCITY-COMPOUNDED IMPULSE TURBINE because the residual velocity of the steam leaving the first row of moving blades is utilized in the second row of moving blades; and, if a third row is added, the velocity of the steam is utilized again in the third row. The fixed blades, which are fastened to the casing rather than to the rotor, serve to direct the steam from one row of moving blades to another.

The velocity-compounded impulse turbine shown in figure 3–6 has only one pressure drop and therefore, by definition, only one stage. This type of velocity-compounded impulse stage is usually called a CURTIS STAGE. Many of the auxiliary turbines used for pumps and forced draft blowers consist of one Curtis stage.

(Velocity-compounding can also be achieved when only one row of moving blades is used, provided the steam is directed in such a way that it passes through the blades more than once. This point will be taken up in greater detail in the discussion of types of steam flow.)

Another way to increase the efficiency of an impulse turbine is to arrange two or more simple impulse stages in one casing. The casing is internally divided by diaphragms which contain nozzles so that the residual steam pressure of one stage is utilized in the following stage. This type of turbine is known as a PRESSURE-COMPOUNDED IMPULSE TURBINE because a pressure drop occurs in each stage, as the steam expands through each set of nozzles. Figure 3–7 shows a pressure-compounded impulse turbine with four stages. A pressure-compounded impulse turbine is often called a RATEAU TURBINE, since it is essentially a series of simple impulse (Rateau) stages arranged in sequence in one casing. Pressure compounded impulse turbines are not commonly used for small auxiliary units.

The PRESSURE-COMPOUNDED REACTION TURBINE (and all reaction turbines are pressure-compounded) employs alternate rows, or stages, of fixed and moving blades which



Courtesy of U. S. Naval Institute

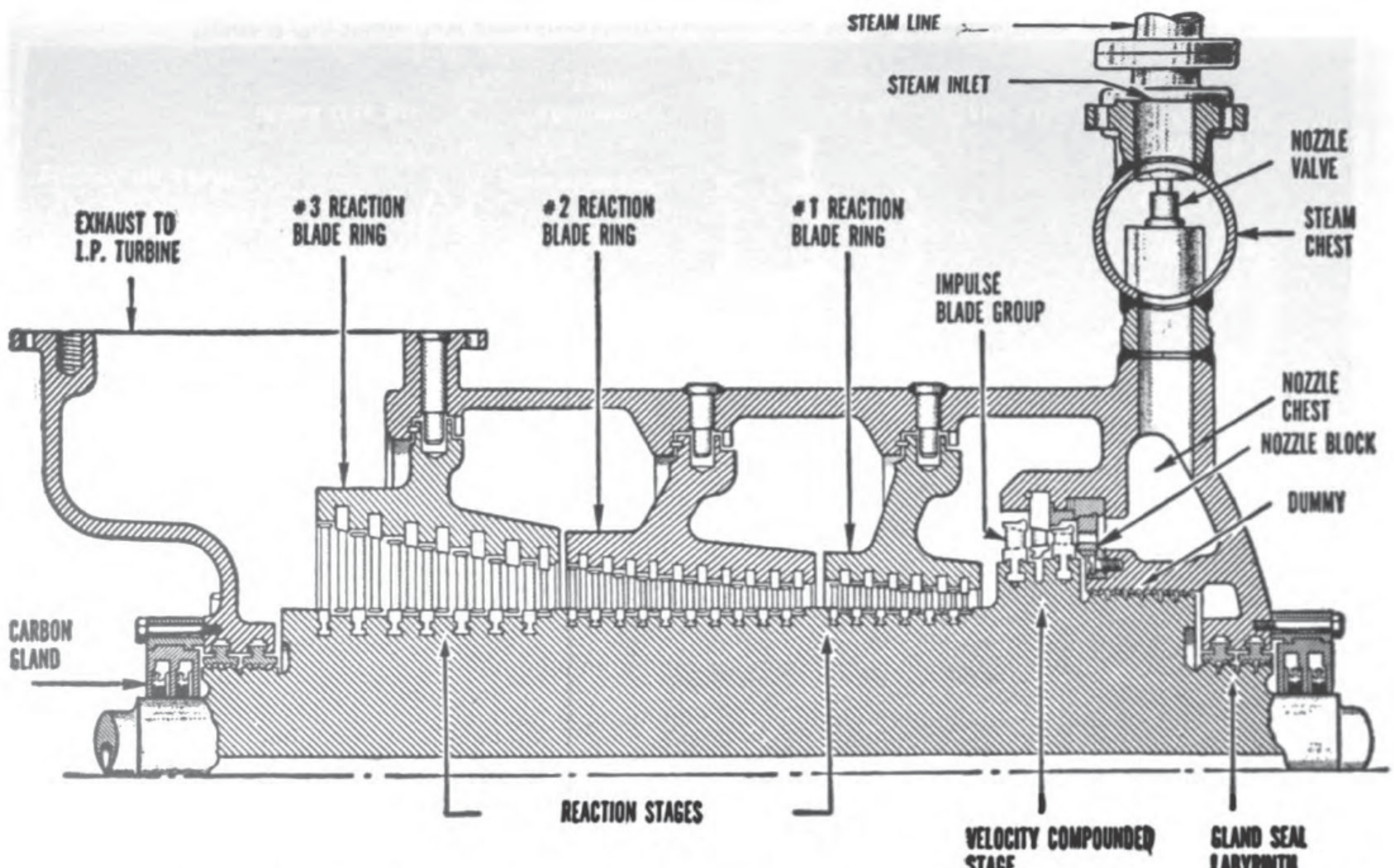
Figure 3–7.—Pressure-compounded impulse turbine.

compound the total pressure drop into as many steps as there are rows of such blades. This pressure staging lowers the steam velocity in each stage.

The COMBINATION IMPULSE AND REACTION TURBINE employs a velocity-compounded impulse (Curtis) stage at the high-pressure end of the turbine. This effects large temperature and pressure drops in the first-stage nozzles, as well as a high initial utilization of thermal energy. It also enables the remaining pressure-compounded reaction stages of the turbine to work more efficiently and with less tendency to distortion in the turbine parts. Figure 3–8 illustrates diagrammatically the design of this type of turbine, which is often referred to as a MODIFIED PARSONS TURBINE.

CLASSIFYING TURBINES BY DIVISION OF STEAM FLOW

The next classification of turbines concerns the number and type of divisions in the steam flow through the several elements which comprise the complete turbine. The turbine types under this classification include single-



Courtesy of U. S. Naval Institute

Figure 3–8.—Combination impulse and reaction turbine (shown diagrammatically).

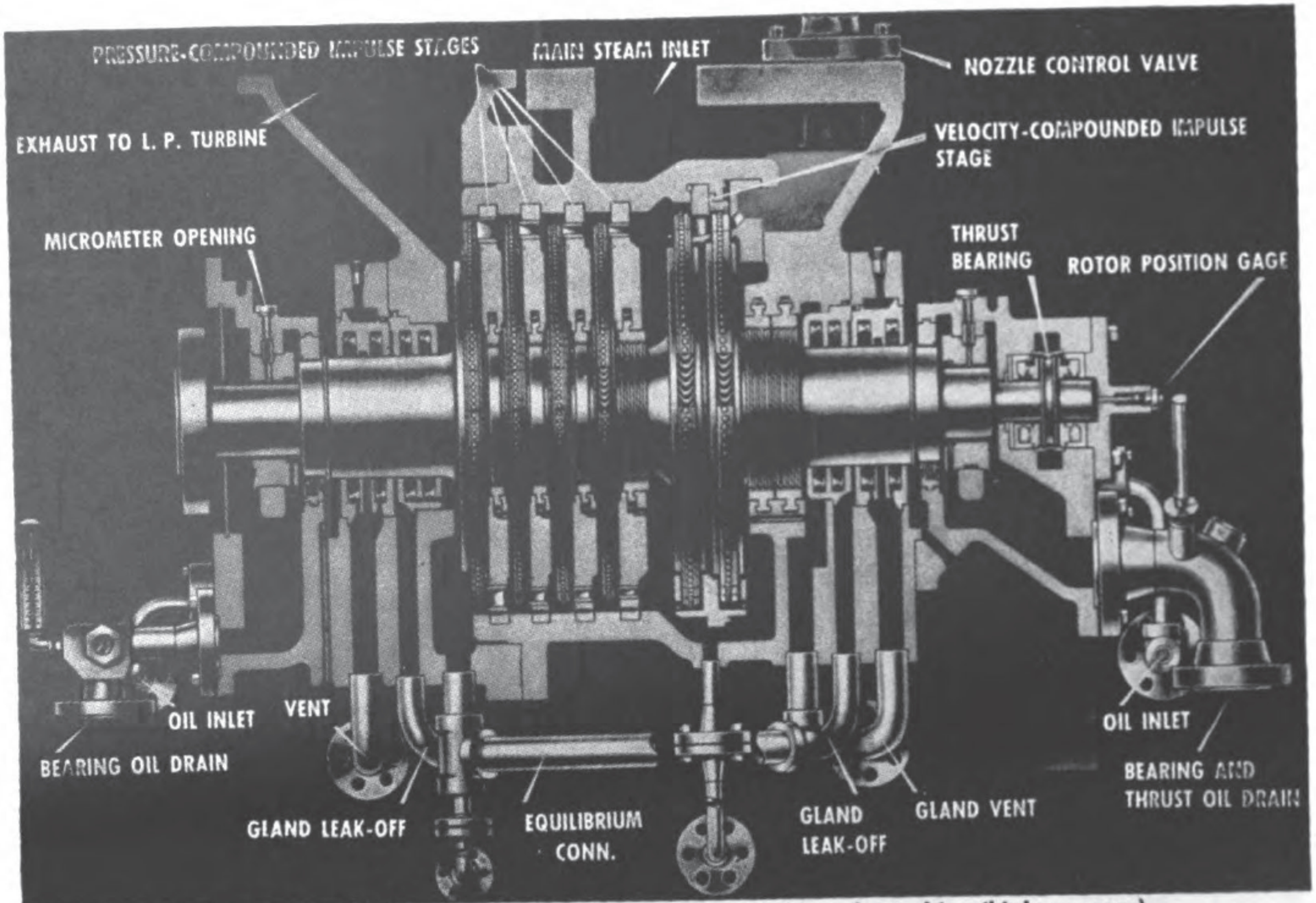


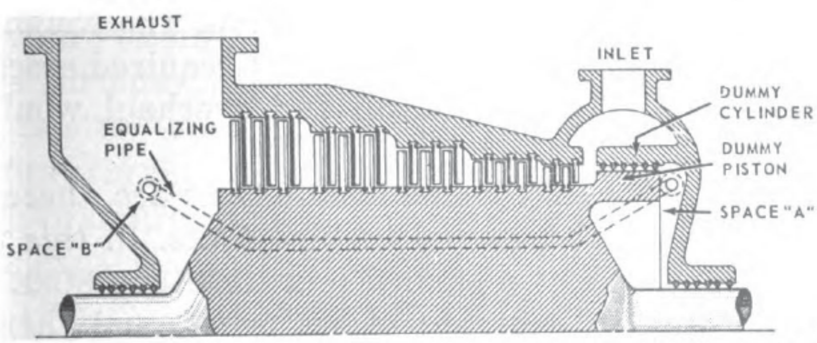
Figure 3–9.—Single-flow pressure-velocity-compounded impulse turbine (high pressure).

flow turbines, cross-compound turbines, and double-flow turbines.

Single-Flow Turbines

In single-flow turbines, the steam enters at the inlet or throttle end, flows once through the blading in a line approximately parallel to the rotor or shaft, and emerges at the exhaust end of the turbine. Figure 3–9 illustrates this type of turbine.

The steam passing through a multistage impulse turbine does not exert any appreciable axial thrust to the rotor since the pressure drop actually takes place in the nozzles. The EQUALIZING HOLES provided in the turbine wheel also help to prevent the development of axial thrust upon the individual wheel of the rotor. In a reaction turbine, however, considerable axial thrust does result from the steam pressure drop since the pressure drop occurs in the moving blades as well as in the stationary blades. In single-flow reaction turbines, this axial thrust is partially counterbalanced by use of a dummy piston and dummy cylinder arrangement such as is shown in figure 3–10. In this arrangement, the space *A*, which sur-



Courtesy of U. S. Naval Institute

Figure 3–10.—Dummy piston and dummy cylinder.

rounds the inlet end face area of the turbine rotor, is connected to space *B*, which surrounds the outlet face end area of the rotor, by an equalizing pipe. The dummy piston and cylinder which form a close running sealing

surface serve to prevent the entry of large amounts of steam from the inlet passage into space *A*. This dummy piston-dummy cylinder and equalizing pipe arrangement thus prevents the formation of a high pressure area at the forward end of the rotor which would exert a relatively large axial thrust toward the low pressure end of the turbine.

In some types of combination impulse and reaction turbines, as for example figure 3–8, a dummy piston and dummy cylinder arrangement similar to the one just described was used to help offset the axial thrust effect caused by the reaction blading of the turbine. In reaction turbines of the double-flow type, which are discussed later in this chapter, the dummy piston and cylinder are not necessary since the axial thrusts developed at each end counterbalance each other.

Compound Turbine Units

In turbine units of small or moderate power, complete expansion of the steam, and resultant utilization of the latent energy, can be provided for in a single casing. For greater power requirements, however, this type of turbine would require casings and rotors of such great size as to create serious difficulties in construction. The weights of these parts would also be so great that required assembly and disassembly for inspection and overhaul would be very difficult.

High-power geared turbine installations are, therefore, generally built as compound turbine units. In this type, the steam is partially expanded in a HIGH-PRESSURE TURBINE (enclosed in a casing of its own), and then exhausted, through a crossover pipe, to a LOW-PRESSURE TURBINE where the expansion is completed. The energy-depleted steam is then exhausted to the main condenser. In some instances, a CRUISING TURBINE precedes the high-pressure turbine. This turbine is operated over the cruising range and may be bypassed at higher powers or speeds.

In more recent designs, a series-parallel turbine is being used. It consists of a single high pressure-intermediate pressure rotor and casing, and a conventional low pressure unit. The high pressure-intermediate pressure steam chest and nozzle-control valves are arranged so that steam is admitted only to the high pressure element for speeds in the cruising range. The steam then passes through an external pipe to the intermediate pressure element and is exhausted to the low pressure unit. For this condition, the turbine is said to be operating in series. For speeds in excess of the cruising range, main steam is admitted to both the high pressure and intermediate pressure elements, and the turbine is operating in parallel. Both the high pressure and intermediate pressure elements exhaust to the low pressure element.

There were originally two general types of compound turbine units in use—the cross-compound and the tandem-compound—but the cross-compound type is the only one now used in the Navy. In these CROSS-COMPOUND TURBINE installations (fig. 3–11), the high and low pressure units are on separate shafts. The two turbine shafts are connected, through reduction gears, to a common shaft which drives the ship's propeller.

CRUISING TURBINES are similar in design to the high-pressure turbines, except that the cruising turbines are smaller in size. When cruising turbines are in use, steam passes first through the cruising turbine before going to the high-pressure turbine (fig. 3–12). In this way, the steam is expanded through a greater number of pressure stages. This extracts more energy from the steam than is possible by use of the high pressure and low pressure turbines. When speeds in excess of the cruising turbine's range are desired or anticipated, the steam is led directly to the high-pressure turbine, bypassing the cruising turbine. Cruising turbines are usually connected to the high-pressure turbine shaft through a reduction gear of the shaft.

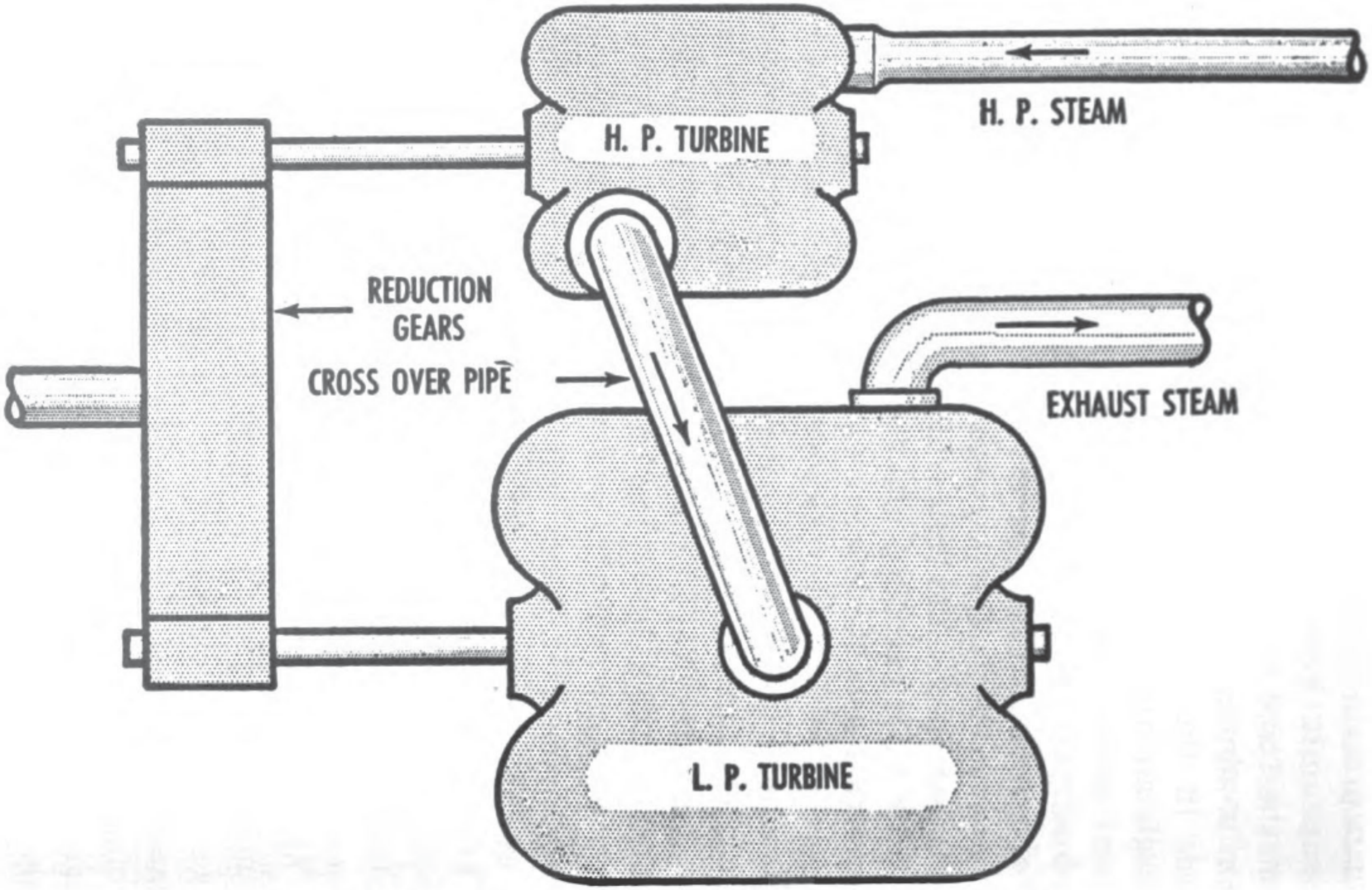


Figure 3–11.—Diagrammatic arrangement of a cross-compound turbine.

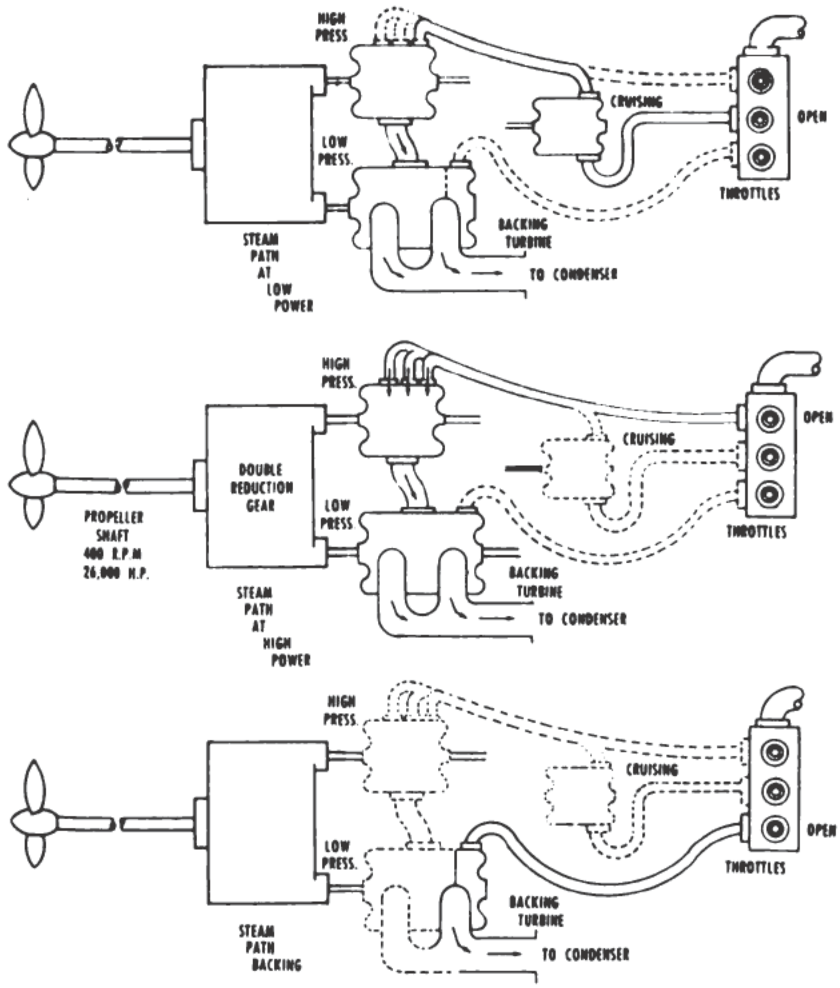


Figure 3-12.—Schematic diagrams of compound turbine cruising arrangements when a cruising turbine unit is included.

The backing or ASTERN TURBINE (fig. 3–12) is bypassed when a ship is going ahead. When this turbine unit, encased with the low-pressure turbine, is cut in, all of the ahead turbine units are bypassed. These turbines may be either single-flow or double-flow impulse turbines, and they develop about one-fifth to one-half of the maximum power of the ahead turbines.

In noncombatant ships, the astern turbine usually consists of one or two velocity-compounded impulse (Curtis) stages mounted on one end of the low-pressure ahead turbine shaft.

Modern combatant type ships with geared turbine installations have an astern element of one or two velocity-

compounded (Curtis) stages installed in each end of the low-pressure casing. This dual element provides higher astern power than is possible with a single astern element. In addition, the axial thrust developed by one element is opposed and balanced by an equal axial thrust developed by the other element.

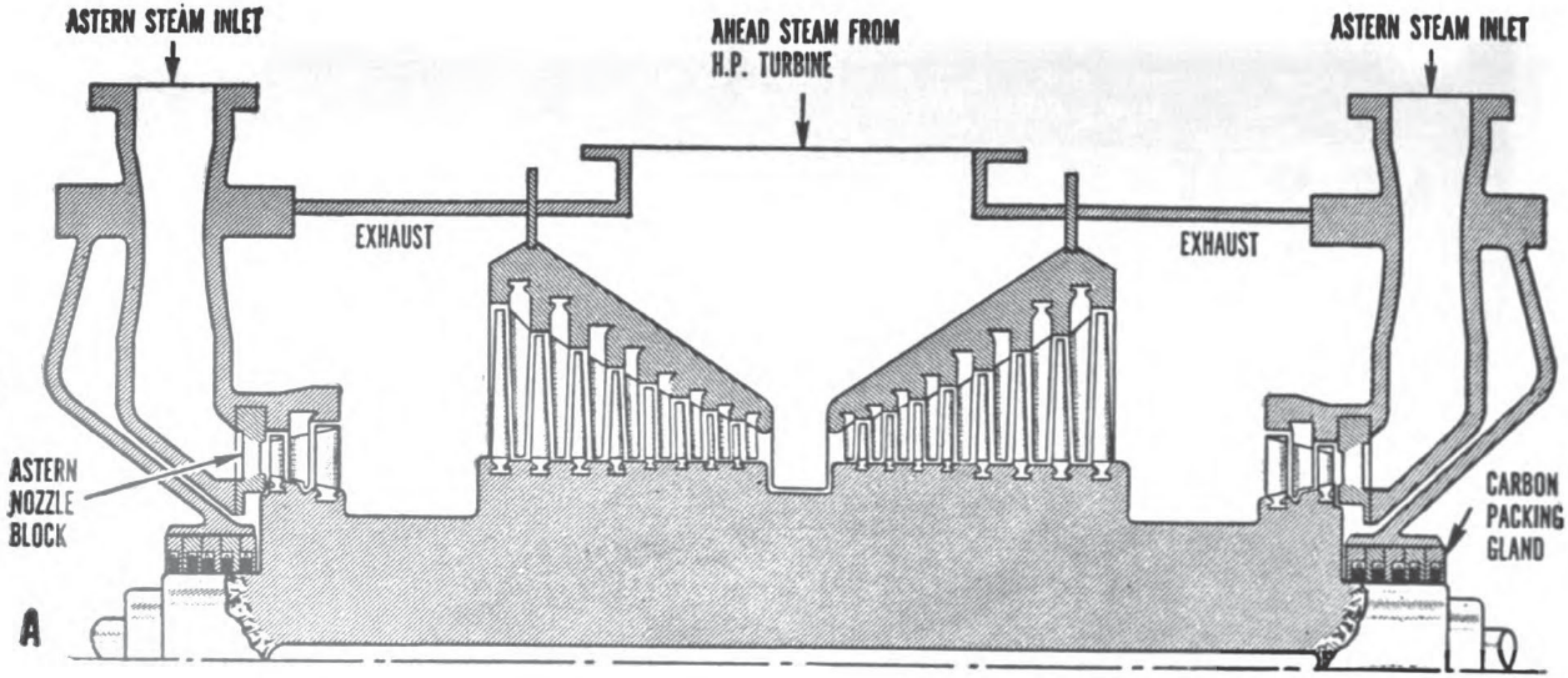
Double-Flow Turbines

Single-flow turbines with a large capacity and a low exhaust pressure require excessively long blades (or a very large turbine diameter) at the low-pressure stages to allow free passage of the expanded steam, and to maintain the desired efficiency. To overcome these disadvantages, LOW-PRESSURE TURBINES are frequently constructed as a double-flow type. This (fig. 3–13, on pages 93 and 94) consists of two single-flow units installed on one shaft, in the same casing, with steam inlet at the center. The blading is arranged to permit steam flow from the center toward both ends, and to give the rotational effect in the same direction at both ends.

Since equal amounts of steam flow from the center toward each end in the double-flow turbine, the steam thrust (pressure toward end of turbine) is balanced, and the undesirable axial thrust is eliminated. The majority of low-pressure compound turbine units are of this type of construction.

CLASSIFYING TURBINES BY DIRECTION OF STEAM FLOW

Turbines may be classified as axial flow, helical flow, or radial flow, according to the direction of the flow of steam relative to the turbine wheel. The Navy uses only the axial flow type for main propulsion units; helical flow turbines are widely used for driving auxiliary machinery; and radial flow turbines are used to a limited extent for small pump drives.



Courtesy of U. S. Naval Institute

Figure 3–13.—(A) Schematic diagram of a low-pressure double-flow reaction turbine.

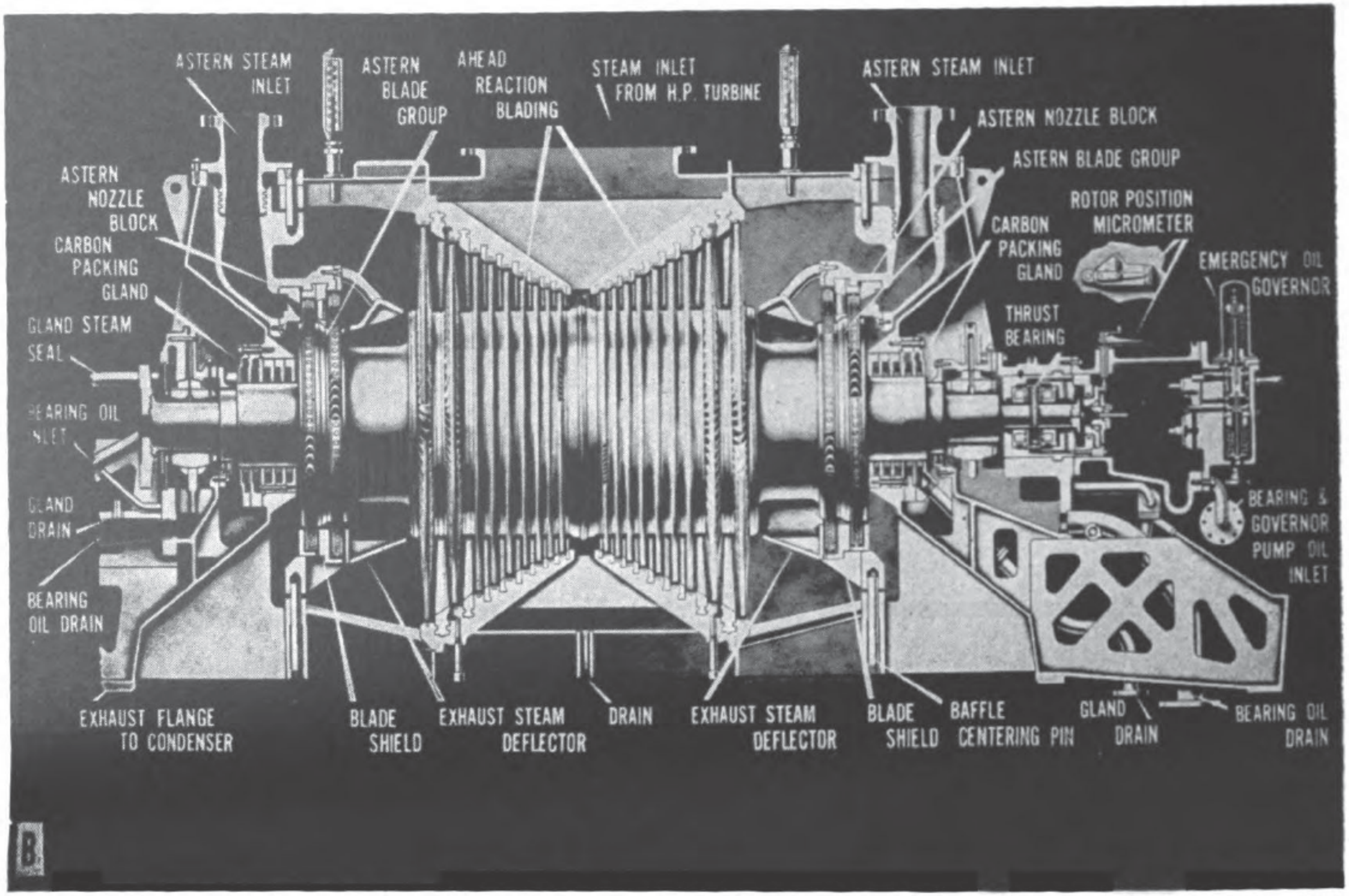


Figure 3–13.—(B) Cutaway view of a low-pressure double-flow reaction turbine. *Courtesy of U. S. Naval Institute*

Axial Flow Turbines

Most steam turbines (especially those of medium and high power), and all of those we have thus far discussed, are of the axial flow type. In such turbines, as the terminology implies, the steam flows in a direction approximately parallel to the axis of the wheel or rotor, the blades being set so that they project radially (or at right angles) from the periphery of the rotor.

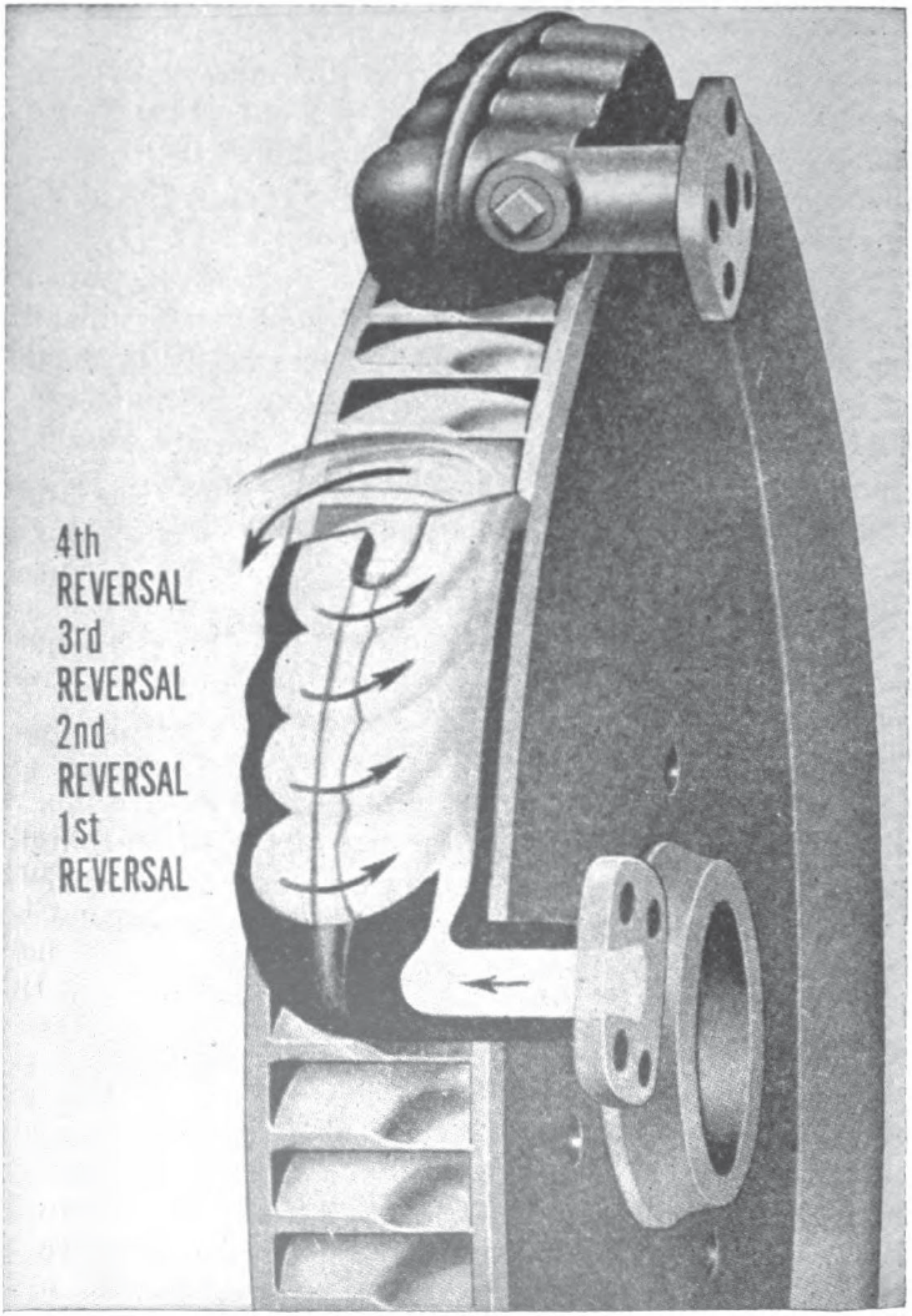
As already indicated, the desired degree of steam expansion in this type turbine is provided for by: increasing the number of rows of blades; increasing the length of blades in successive rows; increasing the diameter of the wheels or rotor upon which the blades are mounted; changing the shapes of the blades or variously spacing them; or a combination of two or more of these methods.

Helical Flow Turbines

In the helical flow (tangential) turbine, the steam flows in the form of a spiral or helix. The rotating element consists of a wheel having semicircular slots, or "buckets," milled obliquely in its periphery or outside circumference. The nozzles (fig. 3–14), are located in such a manner around the circumference of the wheel that the steam flows from them in a direction tangent to the wheel, or so that it impinges upon the slots of the wheel. In this way, the steam is directed into the buckets, and gives a rotational impulse to the wheel. The moving buckets are so shaped that the direction of the steam flow is reversed within them, and the steam is sent back out of the side opposite from where it entered.

The steam coming out of the moving buckets is caught in stationary buckets or REVERSING CHAMBERS, where its direction is again reversed and the steam flows back through the moving buckets. This reversing and redirecting process is repeated several times, after which the steam passes out through the exhaust opening.

A nozzle and the accompanying set of fixed redirecting buckets or reversing chambers are cast or welded in one



Courtesy of U. S. Naval Institute

Figure 3–14.—Phantom view of steam path in a Sturtevant helical flow turbine.

piece. Up to the limit imposed by the circumference of the wheel, any number of these nozzle and bucket sets may be installed. Since the only drop in pressure occurs in the nozzle, this turbine is a single-stage, velocity-compounded, impulse turbine.

This type of turbine is built only in small units, up to a few hundred horsepower, and is used for driving such auxiliary machinery as pumps and forced draft blowers. It has reasonably high efficiency over a wide range of speeds, and is especially adapted to units requiring large speed variations in normal operation.

AUXILIARY STEAM TURBINES

The preceding portions of this chapter have described the general principles and construction features of the various types of turbines in use by the Navy, with particular (though not exclusive) emphasis on the larger types of turbines used for main propulsion. There are, of course, a considerable number of small turbines employed in all naval engineering plants for driving auxiliary machinery such as generators, pumps, air compressors, and forced draft blowers.

Most auxiliary machinery units outside the engineering spaces on modern naval vessels, and many units within these spaces, are driven by electric motors. For example, the usual practice is to duplicate some turbine-driven pumps with electrically driven units to be used at cruising speeds and in port. These motor-driven pumps have a comparatively high efficiency, but their capacity is not great enough to meet the demands of the engineering plant at high speeds.

Efficiency of Auxiliary Turbines

Aside from the fact that the turbine-driven units (particularly pumps) have a higher capacity than the motor-driven units, there are two additional important reasons why turbines are employed to drive the auxiliary machinery:

1. Turbines ensure greater reliability than motor-driven units. The possibility of interruption or loss of electric power supply is greater than the possibility of loss of steam supply—especially during action.
2. Turbines improve the over-all efficiency of the plant by supplying exhaust steam for such auxiliary machinery units as feed water heaters, evaporators, etc., where low-pressure steam is required.

The efficiency of most auxiliary turbines is increased with the use of reduction gears. These turbines are designed to have comparatively few stages (sometimes only one), to conserve space. This results in a large pressure drop in each stage, and a high steam velocity. To obtain maximum efficiency, the blade speed must also be high. Hence, the reduction gears reconcile the two conflicting speed requirements, and increase the general efficiency.

Auxiliary Turbine Classification

In general, auxiliary turbines in naval use may be classified (in a manner similar to the general turbine type classifications) according to the following characteristics.

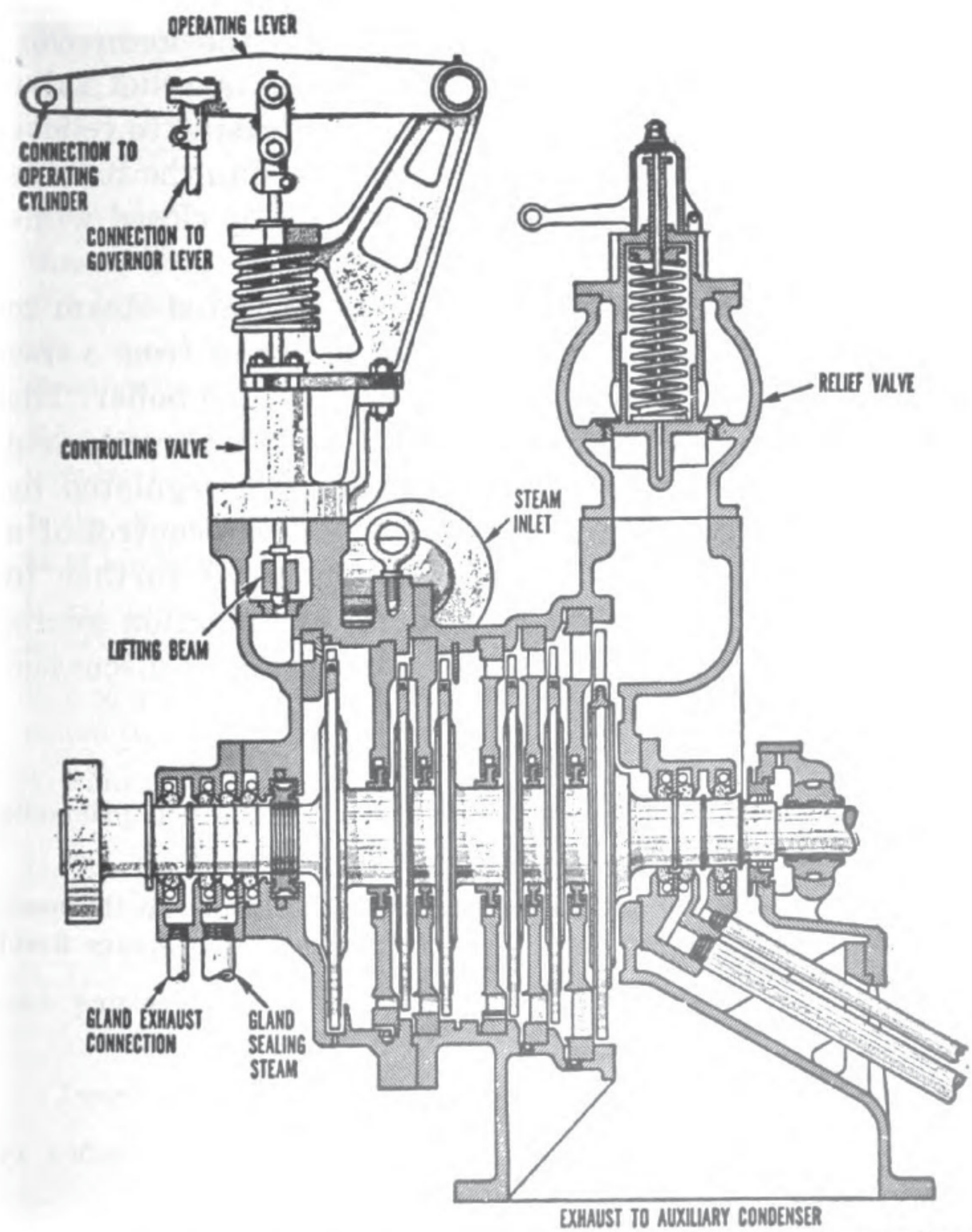
1. Speed (constant or variable).
2. Exhaust conditions (condensing or noncondensing).
3. Shaft position (horizontal or vertical).
4. Type (impulse or reaction).
5. Steam flow direction (axial, radial, or helical).
6. Stages (single or multiple).
7. Drive (direct or geared).
8. Service (based upon driven auxiliary).
9. Power output capacity, limiting speeds, etc.

Except for electric generator turbines, the auxiliary turbines are usually impulse turbines of either the helical-flow or axial-flow type. They operate against a back pressure of 12 or 15 psig, depending upon the auxiliary exhaust line operating pressure of the ship in which installed. In later ships, this back pressure is 15 psi. Turbines for driving the ship's service generators are or-

dinarily of the impulse, axial-flow, multistage, geared type.

Ship's Service Generator Turbine

Figure 3–15 shows a typical ship's service generator turbine for driving a 600-kilowatt a-c generator. The tur-



Courtesy of U. S. Naval Institute

Figure 3–15.—An example of a ship's service generator turbine.

bine is of the axial-flow, pressure-compounded, impulse type. It exhausts to a separate auxiliary condenser which has its own circulating and condensate pumps and air ejector. Cooling water for the condenser is provided by the auxiliary circulating pump through separate injection and overboard valves.

On some ships, in case of condenser casualty, the turbine exhaust may be discharged directly into the auxiliary exhaust line, to the atmosphere, or into the main condenser when the main plant is in operation. A relief valve is always installed on the turbine exhaust casing to relieve excess pressures which would build up within the turbine casing if the exhaust should be inadvertently closed while the turbine is in operation.

Provision is made for supplying superheated steam to the turbine from either the main steam line or from a special turbogenerator line, led directly from the boiler. The steam is admitted to the turbine through a throttle trip valve to the steam chest—the speed being regulated by a number of nozzle control valves under the control of a governor. This type of control is explained further in the next chapter, where such items as reduction gears, bearings, gland sealing systems, etc., are also discussed.

QUIZ

1. With what two types of propulsion drives are you primarily concerned?
2. What four composite turbine elements may make up the main propulsion turbine? Which one will receive the steam first?
3. What speed-reducing unit is provided with a cruising turbine?
4. How is direction accomplished with a turboelectric drive?
5. In what four ways are naval steam turbines classified or grouped in this text?
6. What happens to the high velocity of the steam leaving the nozzle block of an impulse turbine?

7. The fixed blades in a reaction turbine are similar in function to which part of an impulse turbine? What is the twofold effect?
8. What comprises a simple impulse stage or turbine? What is another name for it? What happens to the steam pressure in the stage?
9. What is meant by "staging" in steam turbines?
10. What is meant by pressure staging?
11. What is meant by velocity staging?
12. What is another name for a pressure-staged turbine? May as many as 25 successive drops in pressure be found in such a turbine?
13. What is a Curtis-type turbine?
14. How does the construction of a Curtis turbine differ from that of a Rateau turbine?
15. What are the six types of steam turbines, according to their classification by pressure and velocity staging?
16. How is greater efficiency achieved in the velocity-compounded impulse turbine than in the simple impulse turbine?
17. Is the efficiency of an impulse turbine greater at high pressure or at low pressure? Is this the same for a reaction turbine?
18. In the cross-compound turbine, are the high and low pressure units on separate shafts or on a single shaft?
19. Where is the astern turbine element usually located in a compound turbine?
20. Are low pressure turbine elements usually single-flow or double-flow?
21. Is the ship's service generator turbine designed to operate on saturated steam, superheated steam, or both?

CHAPTER 4

TURBINE PARTS AND ACCESSORIES

Now that you have a fairly good idea of the variety and diversity of turbines used in the Navy, we will consider briefly the various unit or component parts, contro's, and accessories of these turbines. These will be discussed only in a general manner. By carefully studying the illustrations in this chapter, you can become familiar with the proper names of turbine parts.

COMPONENT PARTS OF A TURBINE

Exclusive of the controls, the turbine parts which are common to impulse and reaction turbines include foundations, casings, nozzles, (or stationary blades), wheels and rotors, blading, bearings, shaft glands, and gland seals.

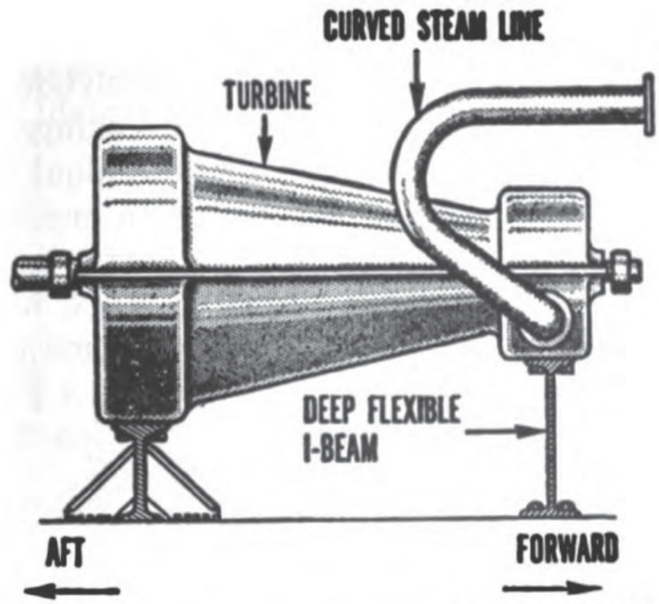
Turbine Foundations

Turbine foundations are built up from strength members in the hull (the transverse and longitudinal beams and girders to which the hull plating is secured) so as to provide a rigid supporting base. All turbines are subject to variations in temperature—from that existing during a secured condition to that existing during a full power condition. Some means must be provided to allow for the expansion and contraction which takes place.

The AFTER END of the turbine is usually secured rigidly by body-bound bolts to a structural foundation which is

built up from the hull of the ship to support the turbine. Body-bound bolts have shanks exactly the same size as the holes in which they are placed—the tight fit preventing all motion. The FORWARD END is allowed a slight freedom of axial movement.

The FREEDOM OF MOVEMENT at the forward end is accomplished by one of two methods: elongated bolt holes or grooved sliding seats may be used to permit the forward end to slide slightly fore-and-aft, as expansion and contraction takes place. The forward end may be secured to a deep, FLEXIBLE I-BEAM (fig. 4–1) installed with its longitudinal axis lying athwartship. When the turbine is



Courtesy of U. S. Naval Institute

Figure 4–1.—Diagrammatic sketch of turbine foundation, showing flexible I-beam.

operating at maximum power this I-beam stands in a vertical undeflected position. When the turbine operates at lower powers, and therefore lower temperatures, the I-beam is deflected slightly aft of the vertical position. The fixed end of the turbine is aft, so that motion due to expansion cannot be transmitted to the reduction gears, where distortion and serious damage would result. STEAM LINES connected to the turbines are bent (as shown in

fig. 4–1) to allow for expansion of the steam line and to relieve strain on the turbines resulting from thermo-stress. Corrugated pipe sections or expansion joints are sometimes used for these bends.

On most of the more modern ships, the main condenser is supported by the low-pressure turbine which is rigidly mounted on beams which form an integral part of the hull structure. In other cases, the low-pressure turbine may be mounted on the condenser.

Turbine Casings

Turbine casings are generally constructed of cast carbon steel. For turbines utilizing superheated steam with temperatures above 650° F, however, the casings are made of cast or fabricated carbon molybdenum steel. When the pressure parts of turbine casings are being assembled, the contact surfaces of individual flanges are given a coating of sealing compound to ensure that the casing joints will be steam tight. Ports, provided for checking the clearances of the first stage blading, are closed by screw plugs or bolted plates. Some turbines, in addition to having inspection ports, have a permanently attached rotor position indicator by which the relative axial position of the rotor may be checked.

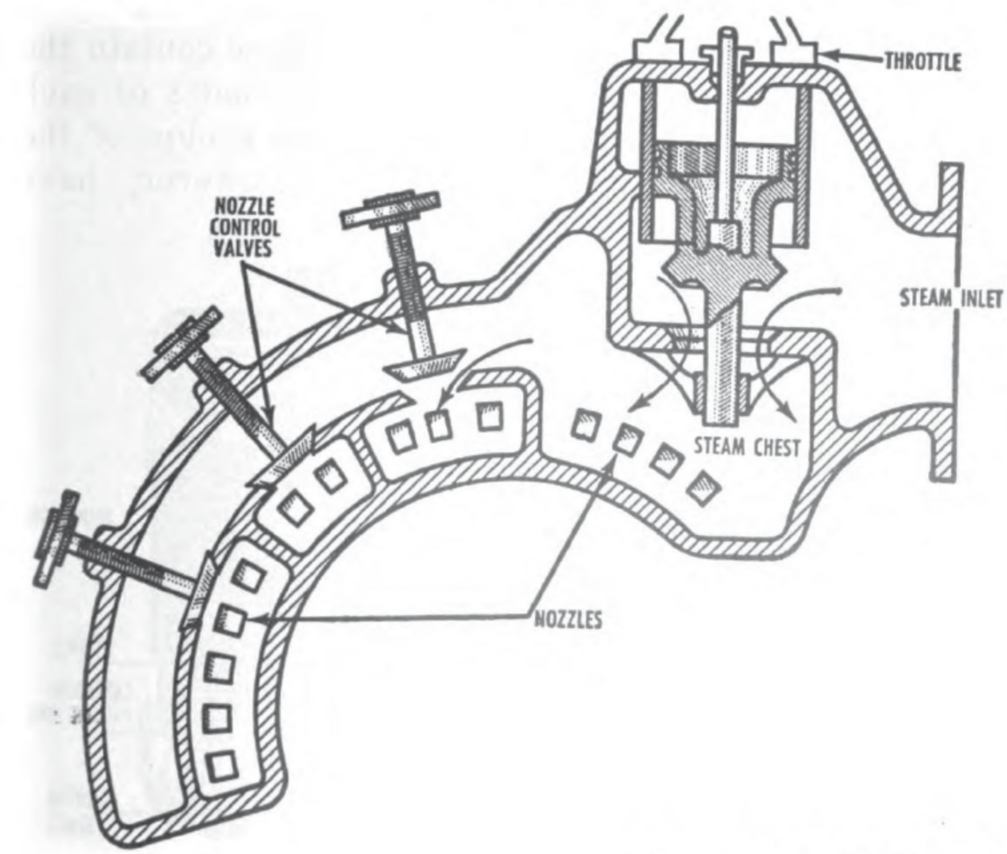
Each casing, as shown in the various illustrations of the preceding chapter, provides for a STEAM CHEST that receives the incoming high-pressure steam and delivers it to the first stage nozzles or blades. An EXHAUST CHAMBER receives the lower pressure steam from the last row of moving blades and delivers it to the next turbine or the condenser.

Nozzles

The primary function of the nozzle, as already described, is to convert the steam's thermal energy into kinetic energy—and thereby increase steam velocity through a reduction in pressure. The nozzle's secondary

function is to direct the steam against the blades. In some installations having a full arc admission the first stage nozzles extend around the entire circle of the first row of blades. In others having only a partial-arc admission, only a section of the blade circle is covered by the nozzles. In most modern turbines the nozzles are made up in groups or blocks, with each group being controlled by a separate nozzle control valve. The quantity of steam delivered to the first stage wheel thus becomes a function of the number of nozzles in use, and the NOZZLE CONTROLS, where hand-operated, supplement the THROTTLE VALVE in governing the speed and power of the engine. This is important from an efficiency standpoint, since the efficiency of a turbine depends to some extent upon a low degree of throttling down through the main throttle.

Figure 4–2 illustrates diagrammatically this arrange-



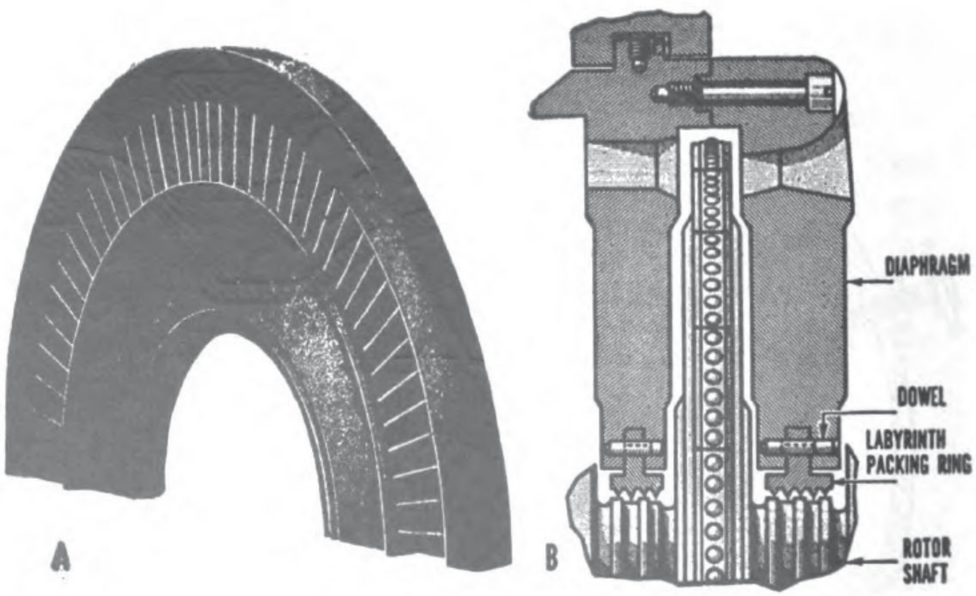
Courtesy of U. S. Naval Institute

Figure 4–2.—Schematic diagram of a nozzle group arrangement.

ment of nozzles in groups. The THROTTLE that you see illustrated admits steam to the STEAM CHEST which, in turn, has an open channel to each NOZZLE CONTROL VALVE. Large speed or load changes are effected by opening additional nozzle control valves. To avoid throttling losses, all the valves in use are opened their entire travel space before an additional valve is cracked open. On some auxiliary turbines these throttle valves are operated manually. On most main turbines they are opened in sequence by controlling cam plates. Where nozzle control valves are cam-operated, the throttle valve is omitted, however, in such case, the control wheel for the cams is usually referred to as the throttle.

Nozzle Diaphragms

NOZZLE DIAPHRAGMS, illustrated in figure 4–3A, are installed ahead of the rotating blades of each stage of a pressure-compounded impulse turbine. These contain the nozzles and admit steam to the rotating blades of each stage in much the same way as the nozzle groups of the first stage. Some nozzle diaphragms, however, have



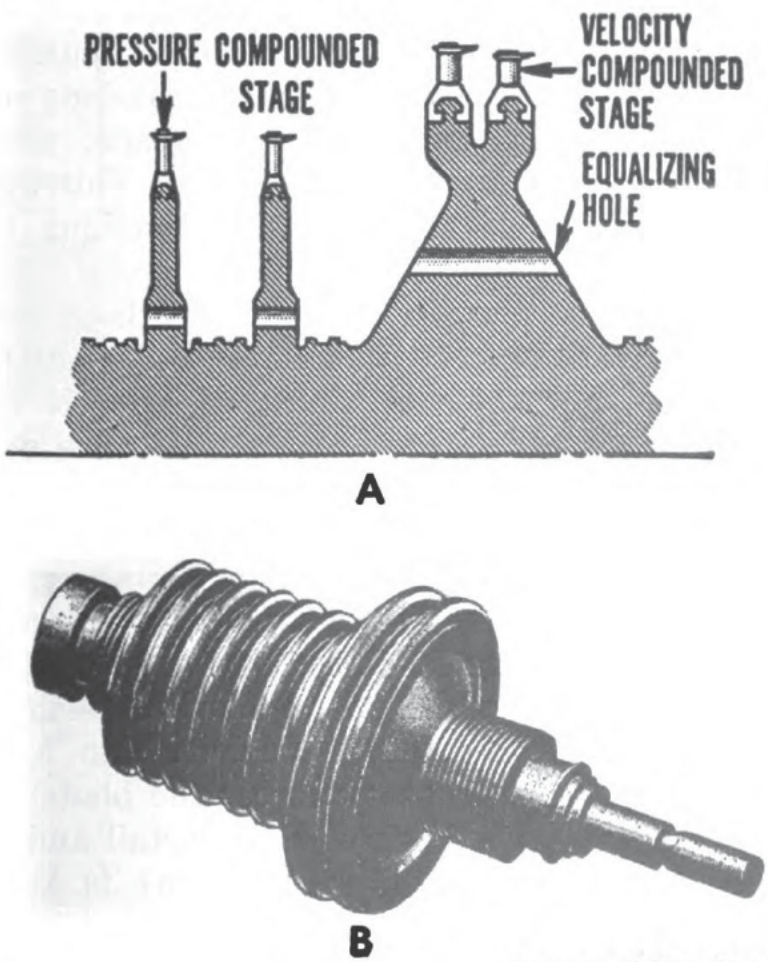
Courtesy of U. S. Naval Institute

Figure 4–3.—(A) Impulse nozzles and nozzle diaphragm. (B) Internal construction.

nozzles extending around the entire circle of blades. The pressure drop existing across each diaphragm necessitates the installation of a packing seal to minimize the flow of steam between the diaphragm and the rotor. For this purpose a labyrinth PACKING RING, similar to the shaft gland packing, is placed in a groove in the inner periphery of the diaphragm. Figure 4–3B illustrates the placement of these rings. Rings are installed in sections and are spring-backed to effect a good seal.

Turbine Rotors

The primary purpose of turbine wheels and rotors is to carry the moving blades which receive the energy from



Courtesy of U. S. Naval Institute

Figure 4–4.—(A) Integrally forged turbine wheels, and (B) turbine rotor with blades detached.

the steam, and turn the turbine shaft. In some of the older installations, the wheels are keyed to the rotor shaft; in most current installations, the wheels are integrally forged with the shaft, as illustrated in figure 4–4A. The rotors (i. e., forged wheels and shaft) are made of carbon steel, if used with steam of comparatively low temperatures, or of carbon-molybdenum steel or other high-temperature creep-resisting alloy steels, if used with steam of temperatures above 650° F. Each of the rotor wheels is grooved to permit attachment of the blades. Figure 4–4B illustrates a turbine rotor without the attached blades.

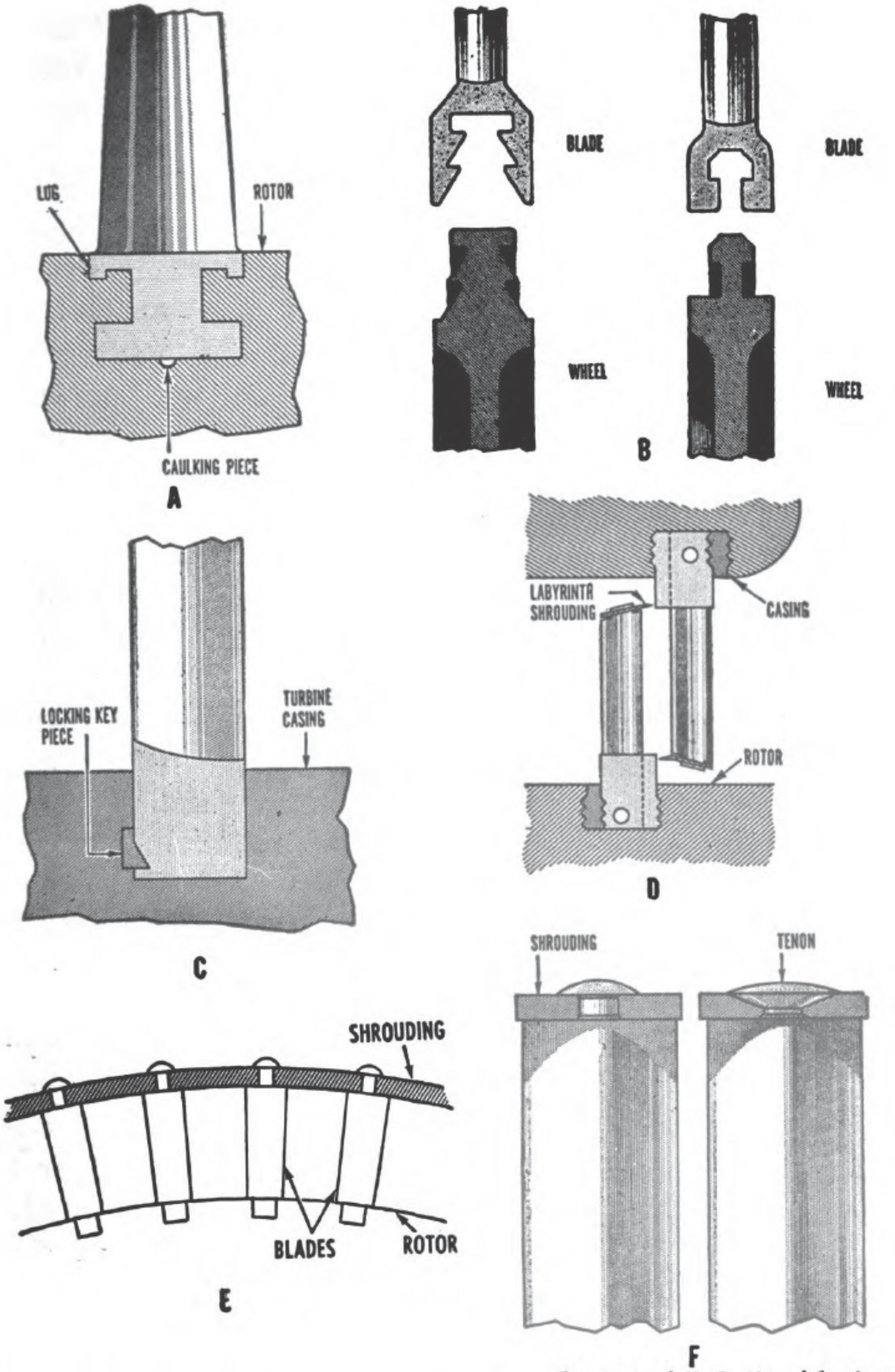
Turbine Blades

Much of the information regarding TURBINE BLADING was given in the preceding chapter, in the discussions pertaining to types of turbines. In these discussions you were told of the significance of the size, shape, pitch, and spacing of the fixed and moving blades. You were also given information regarding the distinctions between impulse and reaction type blading.

It may be well, also, to cover the methods by which these blades are secured to the turbine casings and rotors, and to learn how their continued rigidity is ensured. Figure 4–5 illustrates the methods which are described briefly as follows:

1. The STRAIGHT CIRCUMFERENTIAL DOVETAIL method, shown in figure 4–5A, is primarily for securing rotor blades. Here a dovetail is machined in the rotor (or casing) into which are fitted the dovetailed roots of the blades. Each blade is driven up hard against the one preceding. A CAULKING PIECE, driven into a shallow groove under each blade root, forces the blade roots up firmly against the shoulders of the dovetail and holds it in place. A LOCKING PIECE (not shown) is keyed and caulked into the space between the first and last blades dovetailed into the row.

2. The INVERTED CIRCUMFERENTIAL DOVETAIL method, shown in figure 4–5B, differs from the method described



Courtesy of U. S. Naval Institute

Figure 4–5.—(A) Turbine blade secured by the straight circumferential dovetail method; (B) inverted circumferential dovetail methods of securing turbine blades (single and double shoulder types); (C) turbine blade secured by the side locking key-piece method; (D) turbine blades secured by the saw-toothed serration method; (E) turbine blade shrouding; and (F) methods of securing shrouding to blades.

in the preceding paragraph in that the dovetail is machined into the root of the blade rather than the rotor or casing. This dovetail straddles a circumferential projection machined on the turbine wheel.

The space between the first and last blades of each row is fitted with a NOTCH BLOCK, which is riveted securely into place. The double shoulder or pine-tree type of dovetail is employed for securing the longer blades. This inverted dovetail is used chiefly for impulse blading.

3. The SIDE LOCKING KEY-PIECE method, shown in figure 4–5C, consists of driving a locking key piece between the blade root and the side of the groove in the casing. Both the blade and the casing groove have notches in them so that when the key piece is driven in, it locks the blade root firmly in place. This method is used only on casing blades, which are not subject to the high stresses and centrifugal force of rotating blades.

4. The SAW-TOOTHED SERRATION method, shown in figure 4–5D is used for both rotor and casing blades. In this method, saw-toothed serrations are machined on the sides of the blade roots to mate with similar serrations machined in the rotor or casing groove. When the root is made undersized in width, as illustrated, SIDE LOCKING PIECES are inserted and caulked in to fill the serrations and lock the blades in place.

5. A thin metal strip or SHROUDING, shown in figure 4–5E, is attached to the ends of the blades by small protrusions, called TENONS, illustrated in figure 4–5F. Sections of the shrouding are drilled and fitted over the tenons, which are then peened over to hold the shrouding in place. This shrouding fits over the tips of the blades and blade assembly. In addition, the shrouding serves to restrict steam leakage from around the blades.

Radial Bearings

The rotor of every turbine must be positioned radially and axially by bearings. RADIAL BEARINGS serve the fol-

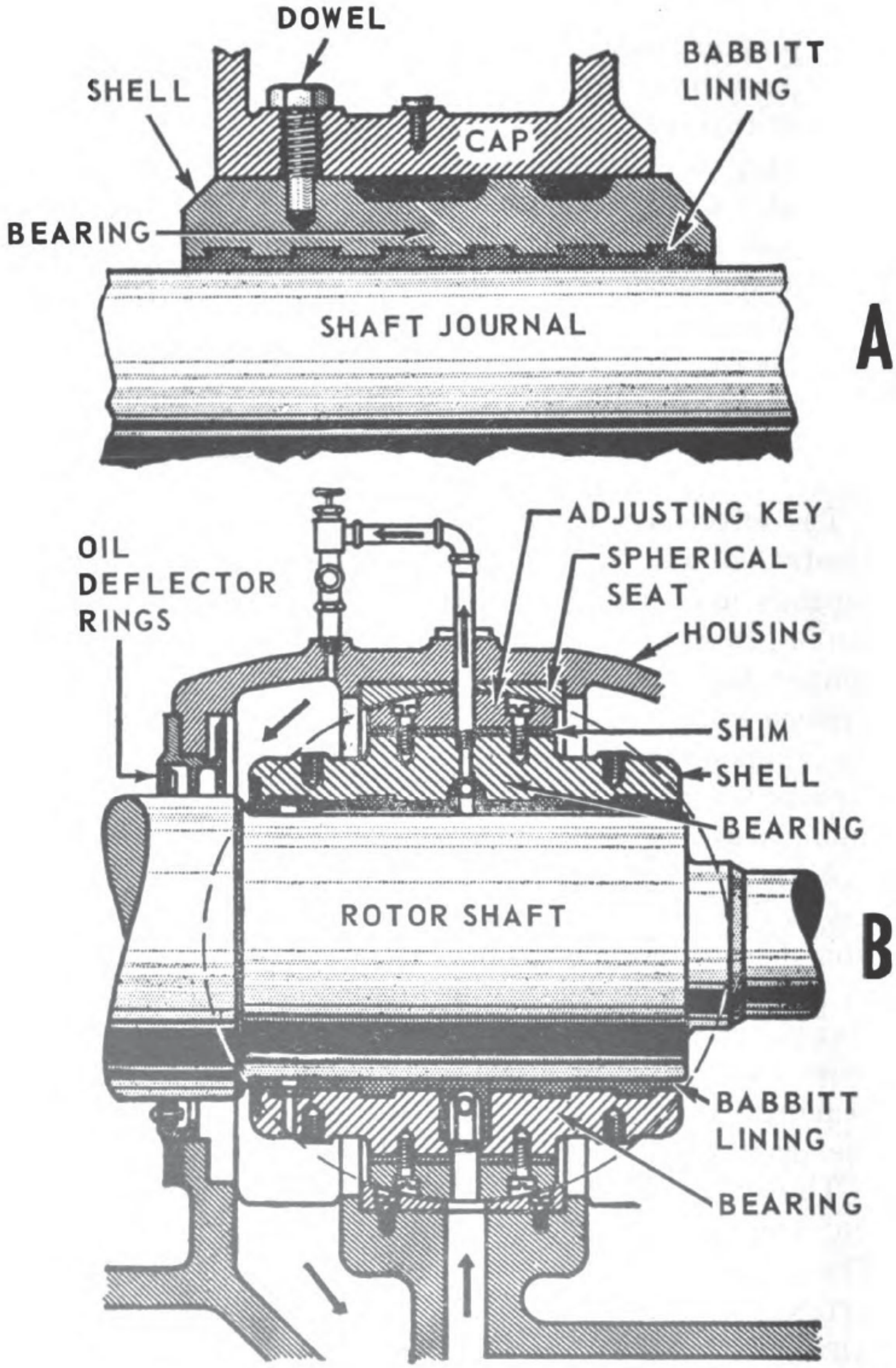
lowing double purpose: to carry the weight of the rotor, and to maintain the correct radial clearance between the rotor and the casing.

Most turbines, including all of the main turbines, have a bearing at each end of the rotor. These bearings are generally known as JOURNAL BEARINGS or SLEEVE BEARINGS, of which there are two types: cylindrical, and spherical-seated. Some small auxiliary turbines employ what are known as ANTIFRICTION BEARINGS, including ball and roller bearings. This discussion, however, is limited to friction type bearings, where two metallic surfaces are separated by and depend upon a fluid oil-film for lubrication.

The effectiveness of this FLUID FILM LUBRICATION, as illustrated and explained in chapter 6, "Lubrication," depends upon a number of factors, including the lubricant's properties of cohesion and adhesion, viscosity, and temperature, as well as the clearance, alinement and surface condition of the bearing and journal. Except for the momentary metal to metal contact at the time the turbine is started, the two metallic surfaces of the journal and bearing are constantly separated by a thin film of oil.

A typical CYLINDRICAL BEARING is illustrated in figure 4–6A. The shell is lined with BABBITT METAL (a composition of tin, copper, and antimony), which is characterized by a tendency to quickly dissipate the friction heat and transfer it to the lubricating oil. A dowel keeps the sleeve from turning. The BEARING CAP, or upper half of the bearing housing, is bolted securely to the lower half of the bearing housing. The bolts are not shown.

The ADJUSTABLE SPHERICAL-SEATED SELF-ALINING BEARING (fig. 4–6B), is used in some modern main turbines. The shell assembly consists of upper and lower CYLINDRICAL SHELLS around which are fitted ADJUSTING KEYS with spherically shaped outer surfaces. This spherical surface fits into a similarly shaped BEARING HOUSING—the spherical shape permits a small amount of shell movement to compensate for minor misalinements



Courtesy of U. S. Naval Institute

Figure 4–6.—Turbine rotor bearings: (A) cylindrical bearings; (B) adjustable spherical-seated bearings.

of the SHAFT. Radial adjustment of the bearing is accomplished either by varying the thickness of the adjusting keys or by placing shims between the adjusting keys and the shells. Since the bearings are located close to the shaft glands, OIL DEFLECTOR RINGS (fig. 4–6B) are fitted to the housing. This prevents leaking gland steam from contaminating the lubricating oil and also prevents the leakage of oil out of the bearing.

Thrust Bearings

Turbine rotors are supported and kept in position by bearings. The bearings which serve to maintain the correct radial clearance between the rotor and the casing are called RADIAL BEARINGS. The bearings which serve to limit the axial (longitudinal) movement of the rotor are called AXIAL or THRUST BEARINGS.

In addition to the radial bearings which serve to support and hold the rotor in correct radial position relative to the casing, a turbine is provided with an axial or thrust bearing. This thrust bearing limits the fore and aft or axial travel of the rotor and thereby maintains the necessary clearance between moving and stationary parts within the turbine.

In some auxiliary turbines, thrust bearings of the ball or roller type are used. In others, the radial bearing is designed to present a small axial bearing surface, as well as the radial bearing surface; this type of bearing is actually, therefore, a combination radial and thrust bearing.

In a small thrust bearing, the babbitt-faced thrust plate is rigidly attached to the bearing housing. To facilitate the entry of lubricating oil to the running surface, the babbitt-faced surface is usually provided with radial grooves. This type of bearing works satisfactorily for light thrust loads and slow shaft speeds. However, in a thrust bearing of a large high-speed turbine or propeller shaft, a rigidly mounted thrust plate, even though grooved, would have difficulty in maintaining an adequate

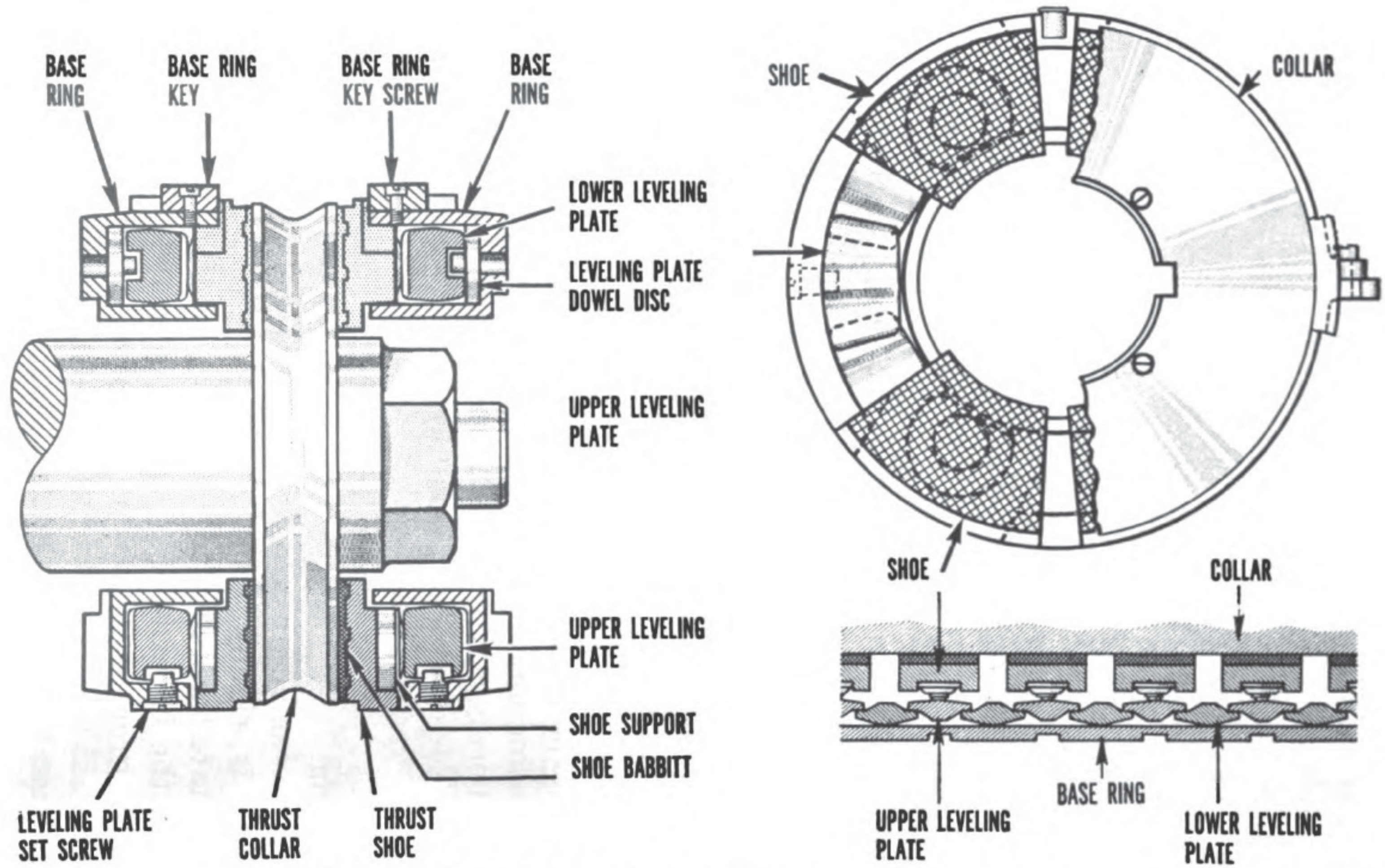


Figure 4-7.—Kingsbury pivoted-shoe thrust bearing.

Courtesy of U. S. Naval Institute

oil film between the thrust face of the bearing and the thrust face of the collar. To overcome this difficulty, main turbine and propeller shafts are equipped with a pivoted shoe (Kingsbury) type thrust bearing (fig. 4–7). In this type of bearing the thrust plate, instead of being a single, rigidly mounted, babbitt-faced piece, consists of a number of babbitt-faced segments or shoes that are free to assume a slight tilt. This freedom to assume a tilt aids in maintaining an adequate oil film between the shoe faces and the thrust collar.

The KINGSBURY THRUST BEARING is made up of the following elements:

1. A THRUST COLLAR which is keyed to the turbine or propeller shaft and rotates with it. The collar transmits thrust from the shaft to an oil film and the shoes;
2. Tilting segments or SHOES which maintain an oil wedge between the collar and the shoes but do not rotate with the shaft. The shoes transmit thrust to leveling plates;
3. An UPPER LEVELING PLATE upon which the shoes rest, and a LOWER LEVELING PLATE upon which the upper leveling plate rests. The leveling plates equalize the thrust load among the shoes;
4. A BASE RING forms the support for the lower leveling plate and transmits the thrust to the ship's structure.

The Kingsbury-type thrust bearing shoes pivot on the upper leveling plates in such a way that they may be tilted very slightly (about 0.001 to 0.002 inches). Because the entire assembly is submerged in oil, the pivoting arrangement allows the formation of a continuous wedge-shaped oil film between the shoes and the thrust collar (fig. 4–8). Whenever the shaft rotates, oil is dragged in (between the collar and each shoe) at the leading edge of the shoe. The thrust on the shaft or collar has a tendency to squeeze the oil out again. Since the oil streams in at the leading

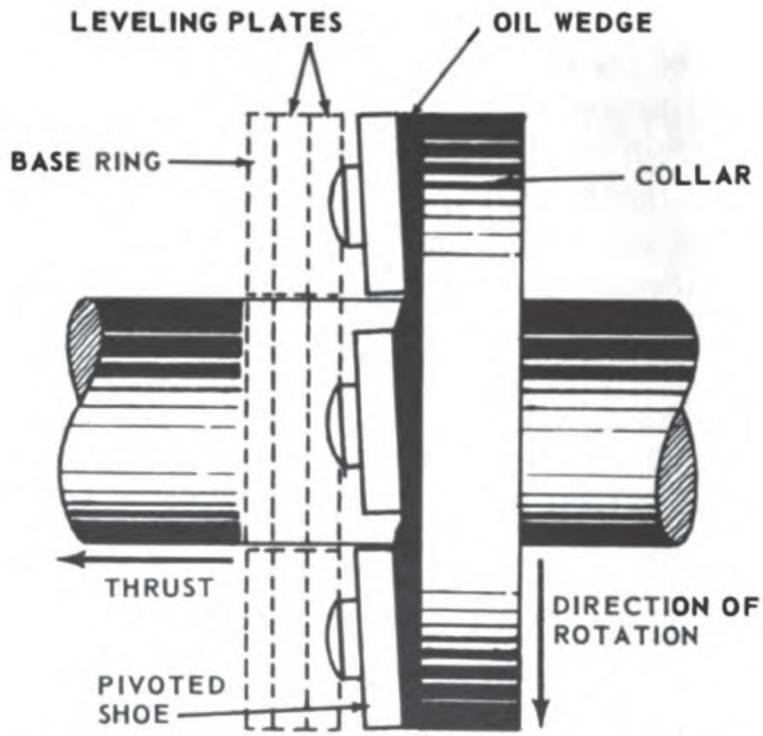


Figure 4-8.—Diagrammatic arrangement of a Kingsbury-type thrust bearing.

edge and goes out at the sides and at the trailing edge, the oil film under the leading edge of the shoe is thicker than at the trailing edge. In other words, as long as the shaft is rotating, each of the shoes is riding on a wedge-shaped oil film.

Turbine thrust is usually in one direction only. Most Kingsbury-type thrust bearings have shoes on both sides of the collar to take care of axial thrust in either direction. In some turbines, where the rotor thrust is always in one direction, or only very slight in the other direction, pivoted shoes are used on the thrust absorbing side only; the non-thrust side has a plain babbitted ring.

A thrust bearing may be installed in a separate housing, or it may be enclosed within the radial bearing housing.

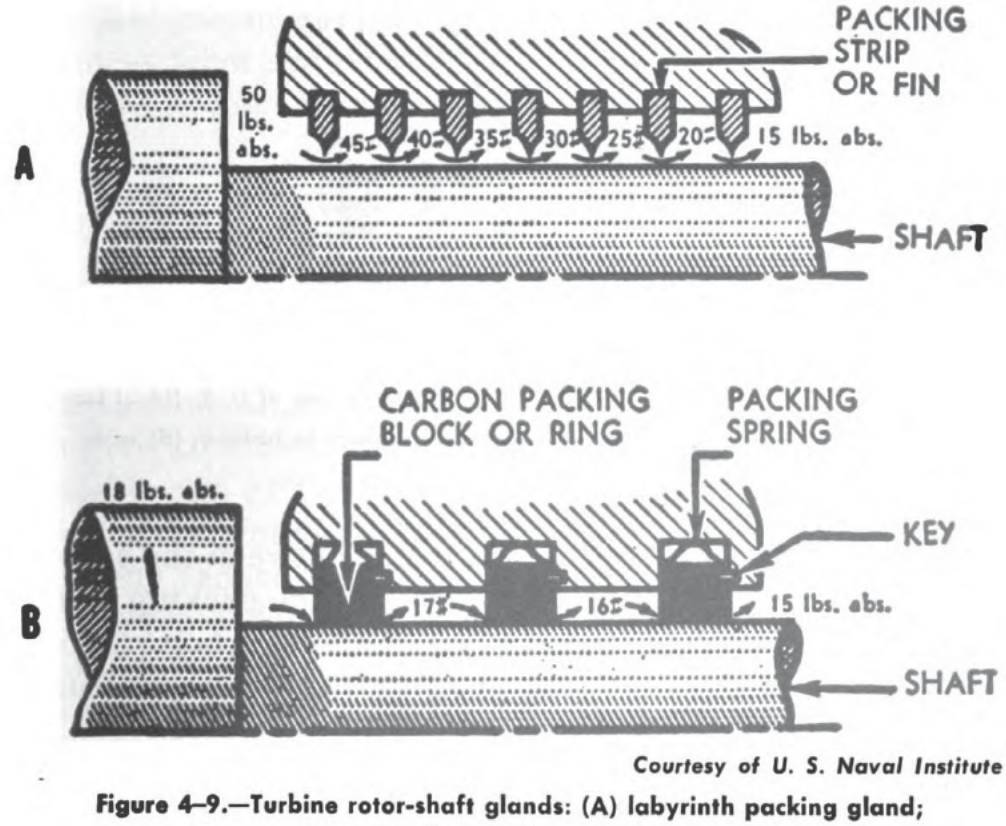
Rotor-Shaft Packing Glands

To prevent leakage around the rotor shaft where it passes through the turbine casing, SHAFT GLANDS are installed. These glands prevent steam from escaping from

the turbine casing when the pressure inside the casing is greater than atmospheric pressure. The packing glands also prevent air from entering the turbine when the pressure within the casing drops below atmospheric.

There are three types of shaft glands most generally used on naval turbine installations—labyrinth packing glands, carbon packing glands, and a combination of both labyrinth and carbon packing glands.

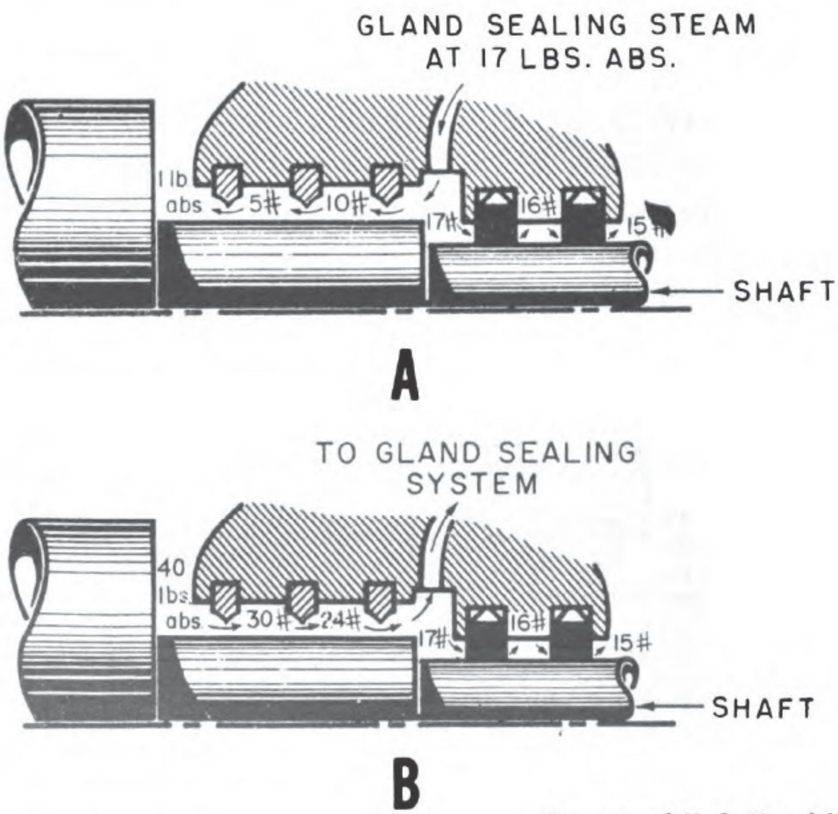
LABYRINTH PACKING GLANDS, shown diagrammatically in figure 4–9A, consist of strips or fins of machined packing mounted on the casing surrounding the rotor shaft. There is a very small clearance between each strip and the shaft. As steam leaks through these narrow clearances the pressure drops. As the steam passes successively from one packing strip to the next, the pressure is gradually reduced to a minimum, and any velocity that the steam might gain by the nozzling effect is lost by an eddy or whirlpool motion.



Courtesy of U. S. Naval Institute

Figure 4–9.—Turbine rotor-shaft glands: (A) labyrinth packing gland; (B) carbon packing gland.

CARBON PACKING GLANDS, illustrated in figure 4–9B, employ the same principle as the labyrinth type. Here, however, carbon packing rings are used instead of the machined packing strips. These rings are mounted around the rotor shaft in segments which are held together with springs and prevented from turning by keys. The carbon segments or blocks are so cut that they have a slightly larger inside diameter than the outside diameter of the

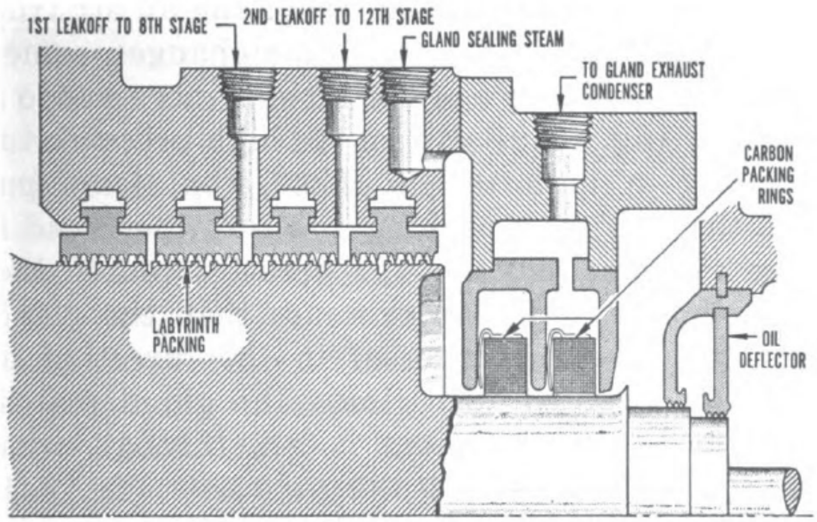


Courtesy of U. S. Naval Institute

Figure 4–10.—Turbine gland (A) with low pressure in turbine; (B) with high pressure in turbine.

shaft. A small quantity of steam leaks between the carbon blocks and the shaft, as it does between the packing strips and the shaft in the labyrinth-type gland. Carbon packing glands are used where low pressures and temperatures exist (fig. 4–10).

A COMBINATION OF LABYRINTH AND CARBON PACKING GLANDS (fig. 4–11) is used in the glands of modern steam



Courtesy of U. S. Naval Institute

Figure 4–11.—High-pressure turbine gland.

turbines. The labyrinth packings are used at the initial high-pressure end of the turbine and for interstage packing. Carbon packing is usually used for shaft sealing at the low pressure ends. Labyrinth packing is used in all instances where prevailing high pressures would cause excessive leakage around the carbon packing.

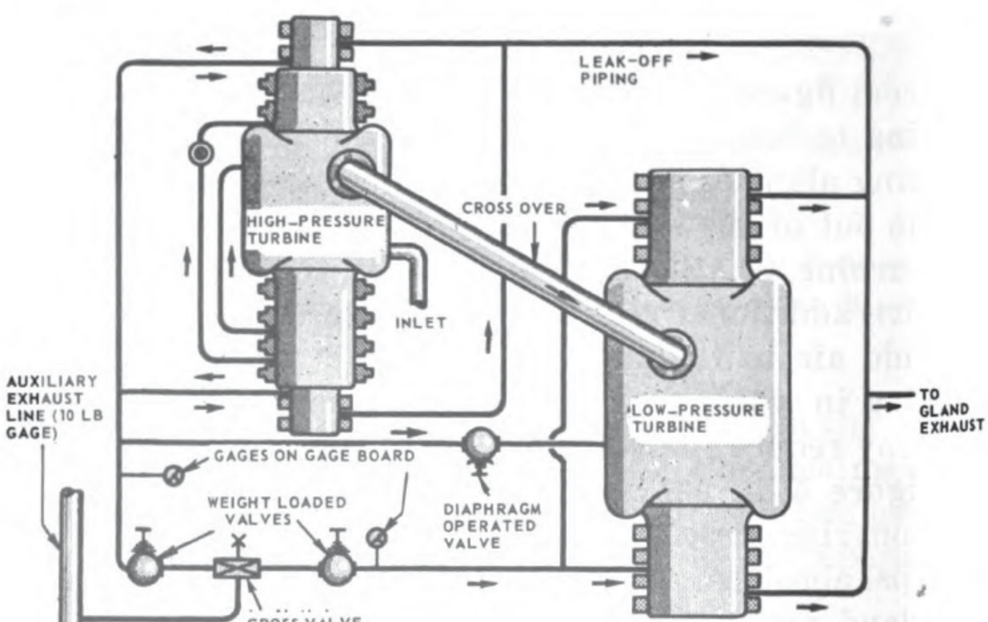
Gland Seals

From figures 4–9, 10, and 11, and the discussions pertaining to rotor-shaft glands, it should be clear that the packing alone of either type will neither stop the flow of steam out of the turbine nor prevent the flow of air into the turbine. GLAND SEALING STEAM is, therefore, employed to give additional required resistance to the entrance of outside air to the turbine. Were this not done, the air leaking in would find its way to the main condenser and thereby reduce the vacuum.

Figure 4–11 shows how this combined labyrinth and carbon ring type gland sealing steam, of about 2 psig (17 psi absolute), is led into a space between the two sets of gland packing. Its pressure being greater than both the atmosphere and the inside pressure of the turbine, the gland steam flows both into the casing and out into the

atmosphere of the engineroom, excluding all air from the turbine in the process. The condition changes, somewhat, when the inside pressure of the turbine increases to above atmospheric (fig. 4–10B) when the high-pressure turbine is operating at high speeds. Then, the steam passing through the labyrinth packing and into the gland steam entrance chamber may, though greatly reduced in pressure, be slightly higher in pressure than the gland seal steam. This causes a reversal in the direction of the gland steam flow. At such times, the gland seal line is closed and the excess steam is led, through what are known as GLAND LEAK-OFF CONNECTIONS (fig. 4–11) to lower stages of the turbine, to the gland condenser, or as sealing steam to other glands. In this particular example, the excess steam leaking past the labyrinth packing is led back into the 8th and 12th stages of the high-pressure turbine. Note that the pressures indicated in figure 4–10 are absolute pressures, and not gage.

Figure 4–12 illustrates diagrammatically a typical GLAND SEALING SYSTEM for modern naval turbines. The gland steam is supplied from the auxiliary exhaust steam



Courtesy of U. S. Naval Institute

Figure 4–12.—A typical turbine gland-sealing system.

line through a cross valve. The two weight-loaded valves B and C operate automatically to maintain a pressure of $\frac{1}{2}$ to 2 psi on the glands. During periods of warming-up, low-speed operation, backing down, and securing, these two valves are open. When the turbine is speeded up, and the steam flowing out of the labyrinth gland of the high-pressure turbine reaches 2 psi, valve B closes automatically and admits no more gland steam from the auxiliary exhaust line. The high-pressure turbine gland is then supplying enough steam leakage to seal the low-pressure glands. As the turbine speed is still further increased, and the pressure in the sealing system rises to about $2\frac{1}{2}$ psi, valve D opens and relieves the pressure by discharging the excess steam either to the low-pressure turbine where it will be advantageously utilized, or to the condenser. The LEAK-OFF CONNECTIONS (fig. 4–11), are linked to the GLAND LEAK-OFF PIPING (shown in fig. 4–12), which collects and condenses the steam that leaks from the glands, thus preventing the escape and loss of steam to the atmosphere.

A fan-type GLAND-SEAL EXHAUSTER (not shown) puts a slight vacuum on the leak-off piping. This vacuum draws the leak-off steam through a GLAND EXHAUST CONDENSER, where the steam is condensed and returned to the feed system.

TURBINE CONTROL UNITS

As an extension of the discussion on parts of the turbine, consider those parts which control or aid in turbine operation. Under this heading are included miscellaneous control instruments, throttle valves, nozzle control valves, bypass valves, and governors.

Control Instruments

Engineroom gages, counters, and control boards vary somewhat in different ships, but the general types and arrangements are the same. The forward engineroom is

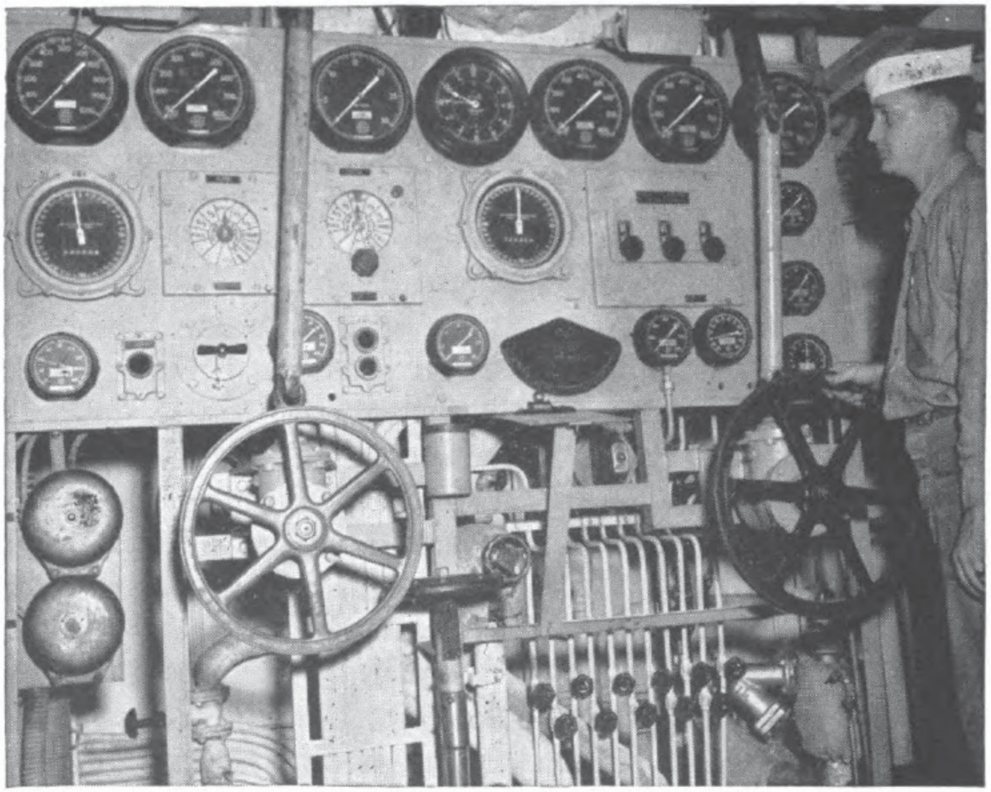


Figure 4–13.—Instrument and gage board of a typical engineroom.

generally the engineering control room, and will contain gages and control boards applying to the ship's entire plant.

GAGES mounted on the gage boards (fig. 4–13) may include those which record the following:

1. Main steam pressure.
2. Steam pressure astern.
3. Vacuum in main condenser.
4. Main feed pump pressure (1 for each boiler).
5. Lube oil service pump pressure.
6. Fire main pressure.
7. Back pressure of exhaust steam.
8. Gland seal pressure.
9. Turbine pressure at the first and last stage of each unit, and at several intermediate stages for the high-pressure turbine.

Other gages, not normally mounted on the gage board

but installed somewhere on or near the main engines, include those which record the following:

1. Vacuum throughout the plant.
2. Flushing line pressure.
3. Deaerating tank temperature and water level.
4. Temperature in turbine casing.
5. Temperature in engineroom space.
6. Salinity of the condensate.
7. Duplicate gages for other engines.

The turbine temperatures, for example, are indicated by thermometers mounted on the turbine casing.

In order that the engineering control personnel may know what propeller speed is being made by the main engines, PROPELLER REVOLUTION INDICATOR SYSTEMS are provided. These systems as now installed are generally self-synchronous electrical transmission systems. Installed on each shaft is a self-synchronous transmitter which is electrically connected to indicators at the engine control stations. These indicators show both instantaneous shaft rpm by a pointer activated by a TACHOMETER arrangement, and total shaft revolutions by the inclusion of a mechanical COUNTER. They also indicate whether the engine is going ahead or backing. The ENGINE ORDER TELEGRAPH (or annunciator) records the general ship speed ordered from the bridge. Slight deviations from these indicated speeds may be ordered from the bridge by means of the REVOLUTION INDICATOR, an instrument on the engineroom gage board which indicates the exact shaft rpm to be obtained at any particular time. A CLOCK is also installed on each board. An ACCELERATION AND DECELERATION TABLE is generally mounted near the control board. This table assists the throttleman in determining the prescribed rates of acceleration and deceleration.

PEG BOARDS of various types are installed throughout the ship. In some cases the pegs on these boards are moved manually. In other cases intricate electrical boards with lights, as illustrated in figure 4–14, are installed. Peg boards you may be concerned with include those for

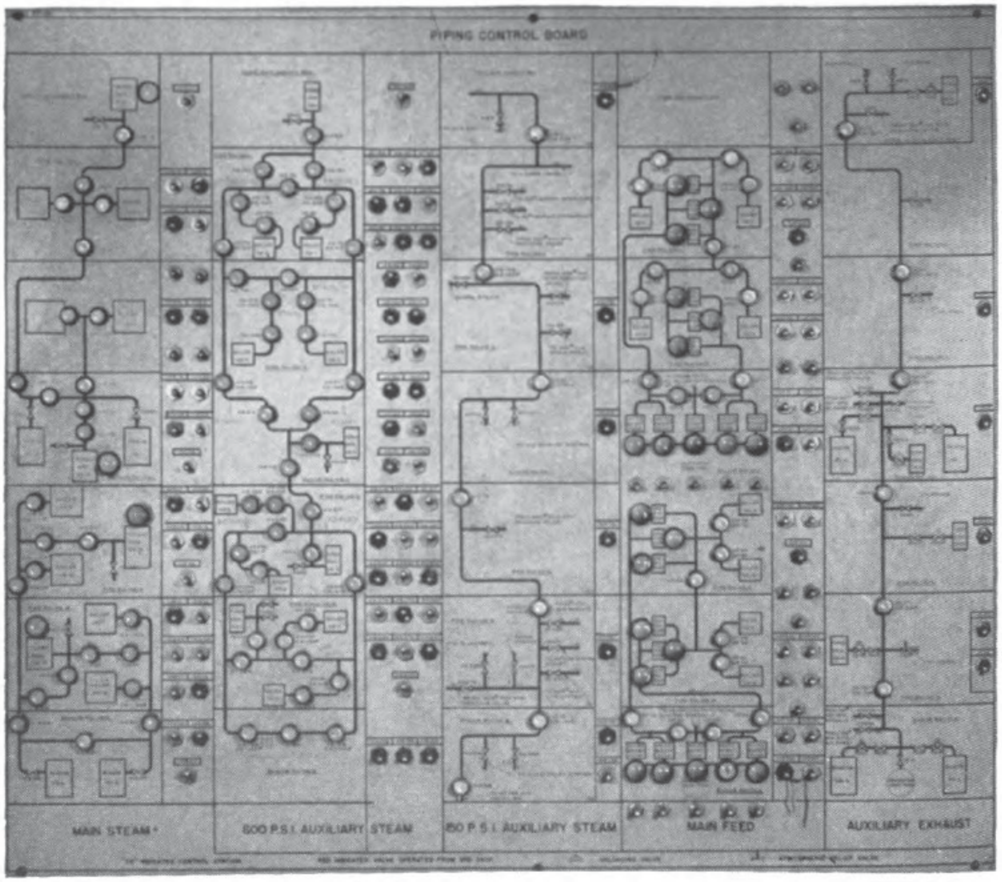


Figure 4–14.—Electrical peg board (piping control board).

the main steam system (located in engineroom), the lube oil system (located in engineroom), the fire main (located in damage control room), and many others. A main steam peg board, for example, will have pegs or lights to indicate which valves in the system are open and which valves are closed at any particular time. The peg board (piping control board) illustrated in figure 4–14 combines unit peg board controls for five engineering systems.

STATUS BOARDS may exist to simplify necessary information regarding the operation status of various engineering systems directly related to the turbines. Figure 4–15A shows a rough sketch of a main propulsion status board, with small levers for each main valve of the plant; a horizontal position indicates an open valve, a vertical position indicates a closed valve. A main control INFORMATION BOARD may be operated to keep essential engineer-

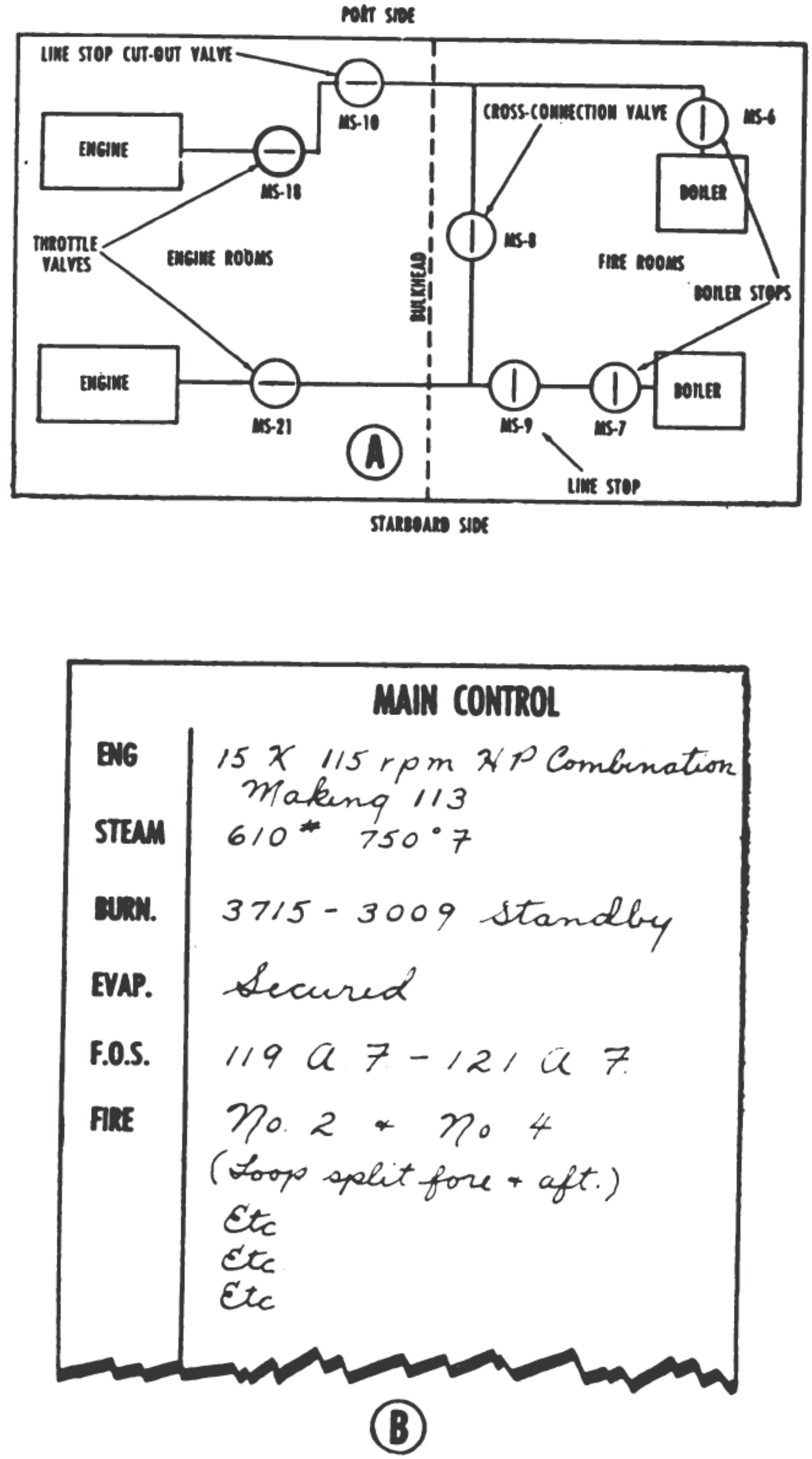


Figure 4-15.—(A) Sketch of a main propulsion status board, and (B) a partial listing of information of a typical main control information board.

ing control information posted in the engineroom. Figure 4–15B indicates some of the information that may be listed on these boards. This information will vary for each ship.

Nozzle Control Valves

To stop, start, or reduce the steam flow to the main propulsion turbines, a system of cam-operated NOZZLE CONTROL VALVES are operated by a single handwheel. The amount of steam entering the high-pressure or cruising turbine depends upon the degree to which the cam-operated nozzle control valves (3 to 7) are opened.

Since space limitations do not permit a detailed discussion of all ship types, the following description of a DD installation will serve to acquaint you with a typical turbine control system.

Three nozzle control valves admit steam to the cruising turbine via the cruising turbine chest. As speed is increased, operating gear (THROTTLE CONTROL VALVE) leading from the main gage board rotates a cam shaft which causes cams to lift three valves successively. There are five valves which admit steam to the high-pressure turbine. These valves are cam operated the same as those of the cruising turbine. The first two of these valves to open admit steam to the first-stage chest (fig. 4–16) of the turbine.

With Nos. 1 and 2 valves fully open, the steam pressure in the steam chest is approximately at line pressure. The first-stage nozzles are passing steam to the first stage at the limit of their capacity. To further increase the power and speed of the turbine, it is necessary to increase the amount of steam flowing through the turbine. To do this, valve No. 3 is opened. This admits steam from the chest through a bypass to the second-stage nozzles. The increased volume and velocity of the steam impinging upon the blading increase the turbine power and speed. With valve No. 3 wide open, it is necessary to open valve No. 4 to obtain a further increase in power. This admits steam

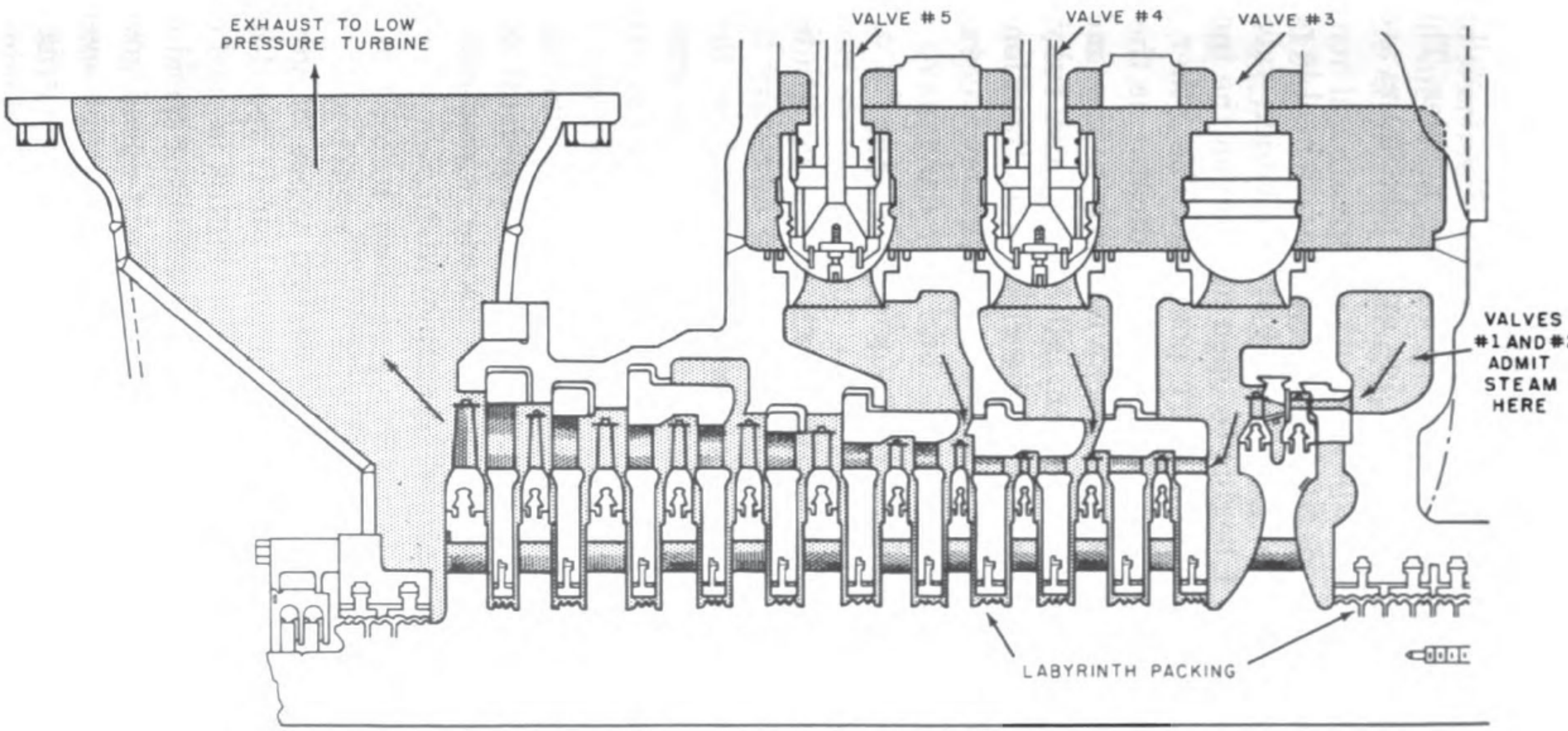


Figure 4–16.—High-pressure turbine showing valve arrangement.

from the chest through a bypass to the fourth-stage nozzles. With this valve wide open, the plant should operate at its full power rpm. Valve No. 5 will, when opened, admit steam to the sixth-stage nozzles. This will permit operation of the turbine at its maximum available speed and power.

On the more modern ships, as the handwheel is rotated, an indicator on the gage board shows which valves are open. Valve No. 1 begins to open as soon as the indicator moves away from the SHUT position. The other valves open at the points indicated on the indicator as the handwheel is turned counterclockwise. When the indicator reaches the OPEN position, all valves are fully open. Turning the handwheel in the clockwise direction closes the valves in the reverse order in which they were opened.

AUXILIARY TURBINE GOVERNORS

Up to this point in the text you have studied the various types of main propulsion and auxiliary turbines and how they work. You have learned how the cam-operated nozzle control valves regulate the amount of steam entering a high pressure or cruising turbine, thereby controlling turbine speed. However, in the auxiliary turbines which are used for driving such auxiliary machinery as generators, forced-draft blowers, pumps, and air compressors, some speed-controlling governor or device must be employed.

Types of Governors

Generally speaking there are two types of governors in use: constant-speed governors and speed-limiting governors. The CONSTANT-SPEED GOVERNOR is used on constant-speed machines to maintain a constant speed regardless of the load on the turbine. Constant-speed governors are usually set so that the turbine cannot even momentarily exceed 105 percent of normal operating speed.

The SPEED-LIMITING GOVERNOR is used principally on

variable-speed machines. A speed-limiting governor allows a turbine to operate under all conditions from no-load to over-load, up to the speed for which the governor is set, but it does not allow operation in excess of 110 percent of normal operating speed. Since this type of governor is adjusted to the maximum operating speed of the turbine, there is no control over the admission of steam until the upper limit of safe operating speed is reached.

Safety Devices

As an added feature on turbogenerator controls, we find four safety devices: an overspeed trip, a back-pressure trip, a low-oil pressure trip, and an emergency hand trip.

The OVERSPEED TRIP shuts off the steam supply to the turbine after a predetermined speed has been reached, and thus stops the unit. Overspeed trips are usually set to trip out at about 110 percent of normal operating speed.

The BACK-PRESSURE TRIP is used to close the throttle automatically whenever the back or exhaust pressure reaches a set pressure.

The LOW-OIL-PRESSURE TRIP is used on turbogenerators to close the throttle if the lubricating oil pressure drops below a specified pressure.

The EMERGENCY HAND TRIP is fitted to all turbogenerators to provide for closing the throttle quickly, by hand, in case of damage to either the turbines or generator. The emergency hand trip may also be used to close the throttle valve when the turbogenerator is secured.

Ship's Service Generator Turbine Governor

Ship's service generators supply electricity for lighting and power throughout a ship. Since a constant voltage must be maintained on ship's service lines, the generator turbine operates, even under greatly varying loads, at a

constant speed. This speed is maintained by means of a constant-speed governor.

A typical ship's service generator turbine control mechanism (fig. 4–17) consists of a centrifugal governor which operates a pilot valve controlling the flow of oil to an operating cylinder. The latter, in turn, controls the amount of opening or closing of the turbine nozzle valves.

A gear-type oil pump and the main governor, mounted on the same shaft, are driven through a worm and gear (fig. 4–17). The worm is directly connected to the low-speed gear shaft of the turbine reduction gear and thereby drives the governor at a speed that is directly proportional to the turbine speed.

The turbine nozzle valves are operated by a lifting beam (fig. 4–17). The nozzle valve stems, of varying lengths, are designed so that they slide freely through holes in the lifting beam. As the beam is moved up and down, the nozzle valves open and close in a predetermined sequence.

Governor Operation

When a governor tends to slow down, because of an increased load on the generator, the governor weights move inward and cause the pilot valve to move upward. This permits oil to enter the operating cylinder. Thus, the operating piston rises and, through the controlling-valve lever, the lifting beam is raised. The nozzle valves open and admit additional steam to the turbine. This upward motion of the controlling-valve lever causes the governor lever to rise, thus raising the bushing. Upward motion of the bushing tends to close the upper port, shutting off the oil flow to the operating cylinder; this stops the upward motion of the operating piston. The purpose of this follow-up motion of the bushing is to damp the governing action of the pilot valve. Without this feature the pilot valve would operate, with each slight variation in turbine speed, to alternately fully open and fully close the nozzle valves.

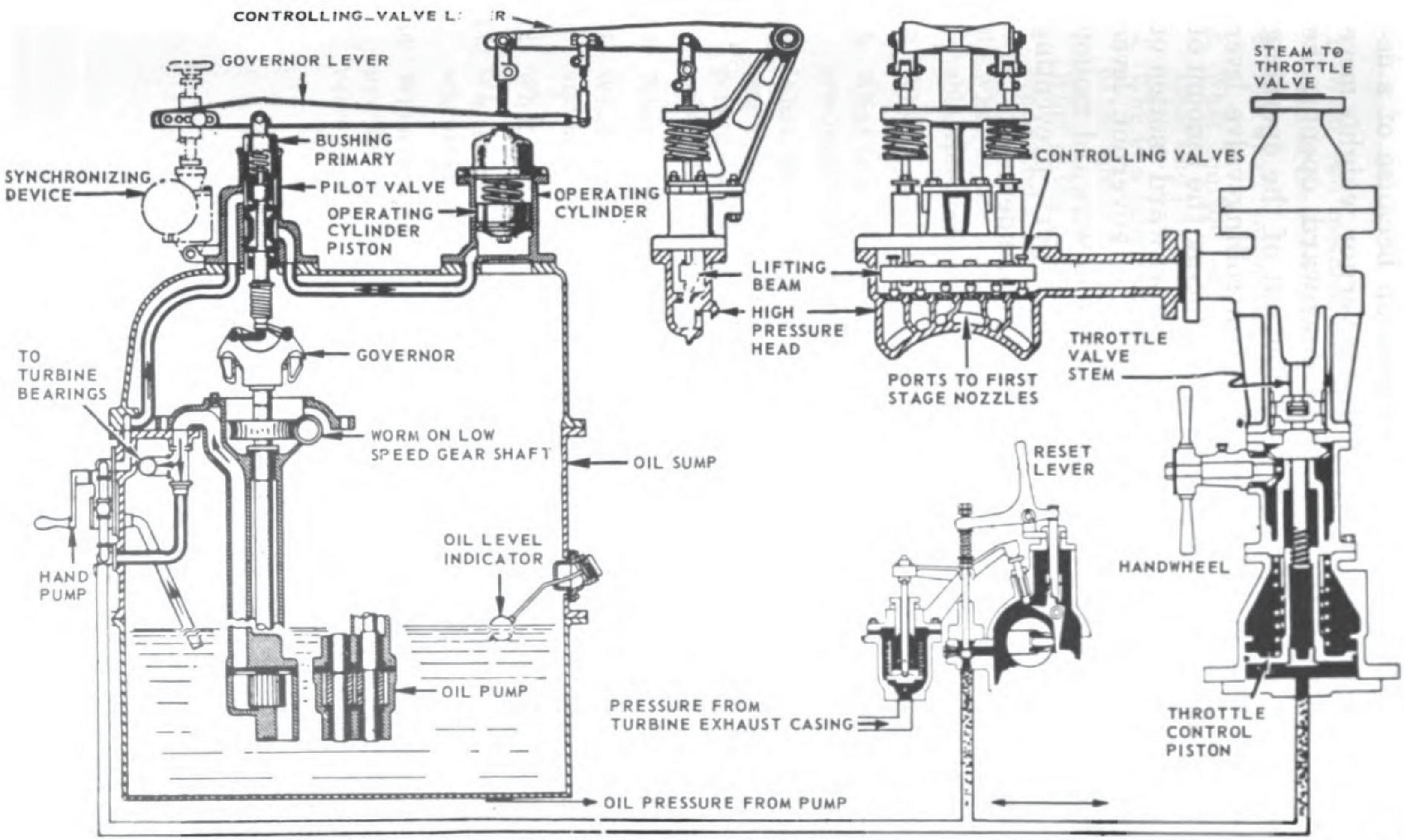


Figure 4–17.—Ship's service generator turbine control mechanism.

Courtesy of U. S. Naval Institute

When the turbine tends to speed up because of a decreased load on the generator, the governor weights move outward, moving the pilot valve downward, opening the lower ports, and allowing oil to flow out of the operating cylinder. This action causes the controlling-valve lever to lower the lifting beam, thereby reducing the amount of steam delivered to the turbine. The downward motion of the controlling-valve lever causes the governor lever to lower; this lowers the bushing. The downward motion of the bushing tends to close the lower port, preventing oil from flowing out of the operating cylinder.

QUIZ

1. What two methods are used to accomplish freedom of movement at the forward end of a turbine foundation?
2. For what reasons are main steam lines bent?
3. What controls supplement the throttle valve in governing the speed and power of the main engine?
4. Why is a labyrinth packing ring placed around the inner web of the nozzle diaphragms of the main turbine?
5. What is the purpose of the babbitt metal lining of a cylindrical bearing on a turbine shaft?
6. What is the significance of the spherical shape of the adjustable, spherical-seated, self-alining, turbine bearing?
7. What type of thrust bearing is used in the main engine turbine?
8. What is the purpose of gland sealing steam in a turbine? Approximately what pressure is maintained?
9. What three general types of turbine rotor shaft glands are employed? Which type is used where high pressure and temperatures prevail, such as the high-pressure stages of a turbine?
10. What is the function of the gland-seal exhauster?
11. What controls the amount of steam flowing to the cruising and high-pressure turbines?
12. What two types of turbine governors are in general use?
13. Which turbine safety device will close the throttle automatically whenever the back pressure reaches a set pressure?
14. When a ship's service generator turbine governor tends to overspeed, in which direction do the flyweights and the pilot valve move?

CHAPTER 5

REDUCTION GEARS, BEARINGS, SHAFTING, AND PROPELLERS

Figure 5–1 illustrates some of the more common forms of gears that are found in various pieces of shipboard machinery. We will not attempt to go into a discussion of the differences of these gears. However, you should familiarize yourself with figure 5–1 so that you will be able to recognize any of these gears when found in combinations as in reduction gearing. Probably one of the simplest types of reduction gearing is the worm gear which you will find in auxiliary machinery. In more complicated gearing as in main reduction gearing of modern combatant ships, you will find double helical gears.

As was pointed out in chapter three, steam turbines must operate in a relatively high rpm range for greatest efficiency while propellers operate most efficiently in a relatively low rpm range. One means of accomplishing the necessary step down from high turbine shaft rpm to lower propeller shaft rpm is by use of an electric drive. The most common means of obtaining the required rpm is by use of reduction gears.

The use of reduction gears is by no means limited to ship propulsion. Other steam turbine-driven machinery such as ship's service generators, air compressors, and various pumps also have reduction gears. In these, like in

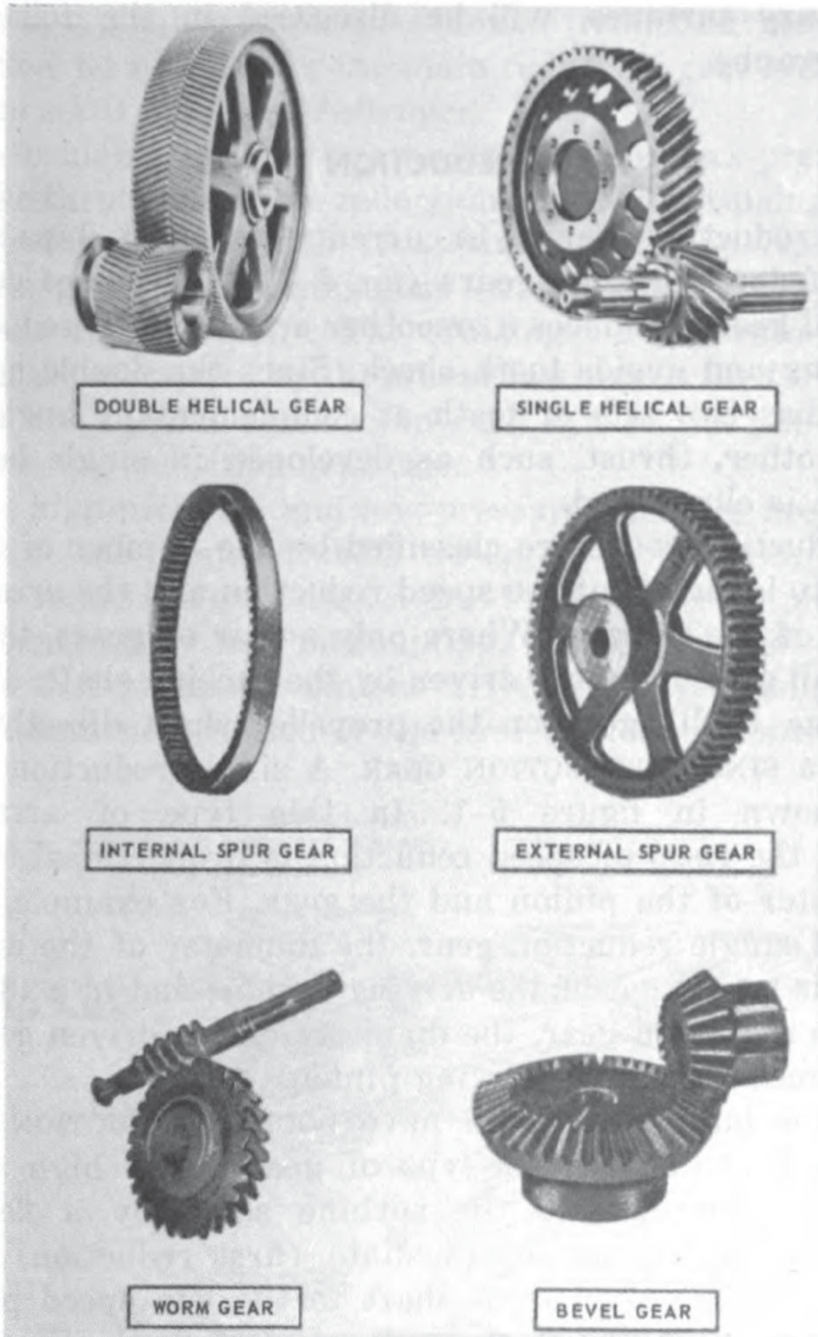


Figure 5-1.—Types of gears found in shipboard machinery.

ship propulsion units, turbine operating efficiency requires a higher rpm range than that suitable for the driven unit.

The construction, operation, and minor maintenance of main reduction gears, as those used with propulsion turbines are called, and those used on some of the

auxiliary turbines, will be discussed in the following paragraphs.

MAIN REDUCTION GEARS

All reduction gearing in current combatant ships make use of double helical gears (fig. 5–1). The use of double helical gears produces a smoother action of the reduction gearing and avoids tooth shock. Since the double helical gear has two sets of teeth at complementary angles to each other, thrust, such as developed in single helical gears, is eliminated.

Reduction gears are classified by the number of steps used to bring about the speed reduction and the arrangement of the gearing. Where only a pair of gears, that is a small gear (pinion) driven by the turbine shaft, drives a large (bull) gear on the propeller shaft directly, we have a SINGLE REDUCTION GEAR. A single reduction gear is shown in figure 5–1. In this type of arrangement, the ratio of speed reduction is proportional to the diameter of the pinion and the gear. For example, in a 2 to 1 single reduction gear, the diameter of the driven gear is twice that of the driving pinion; and in a 10 to 1 single reduction gear, the diameter of the driven gear is ten times that of the driving pinion.

Ships built since 1935 have DOUBLE REDUCTION PROPULSION GEARS. In this type of gear set, a high speed pinion, connected to the turbine shaft by a flexible coupling, drives an intermediate (first reduction) gear which is connected by a shaft to the low speed pinion which in turn drives the bull gear (second reduction) mounted on the propeller shaft. Thus, for example, a 20 to 1 speed reduction might be accomplished by having a ratio of 2 to 1 between the high speed pinion and the first reduction gear, and a ratio of 10 to 1 between the low speed pinion on the first reduction shaft and the second reduction gear on the propeller shaft ($6000 \div 2 = 3000 \div 10 = 300$).

For a typical example of a double reduction gear application, let us consider the main reduction gear installation on a DD 692 class destroyer.

The cruising turbine is connected to the high-pressure turbine through a single reduction gear. The cruising turbine rotor carries with it a pinion which drives the cruising gear; the cruising gear being coupled to the high-pressure turbine shaft. The cruising turbine rotor and pinion are supported by three bearings, one at the forward end of the turbine and one on each side of the pinion in the cruising reduction gear case.

The high-pressure and low-pressure turbines are connected to the propeller shaft through a locked-train type double reduction gear (fig. 5–2). First reduction pinions are connected by flexible couplings to the turbines. Each of the first reduction pinions drives two first reduction gears. Attached to each of the first reduction gears by a

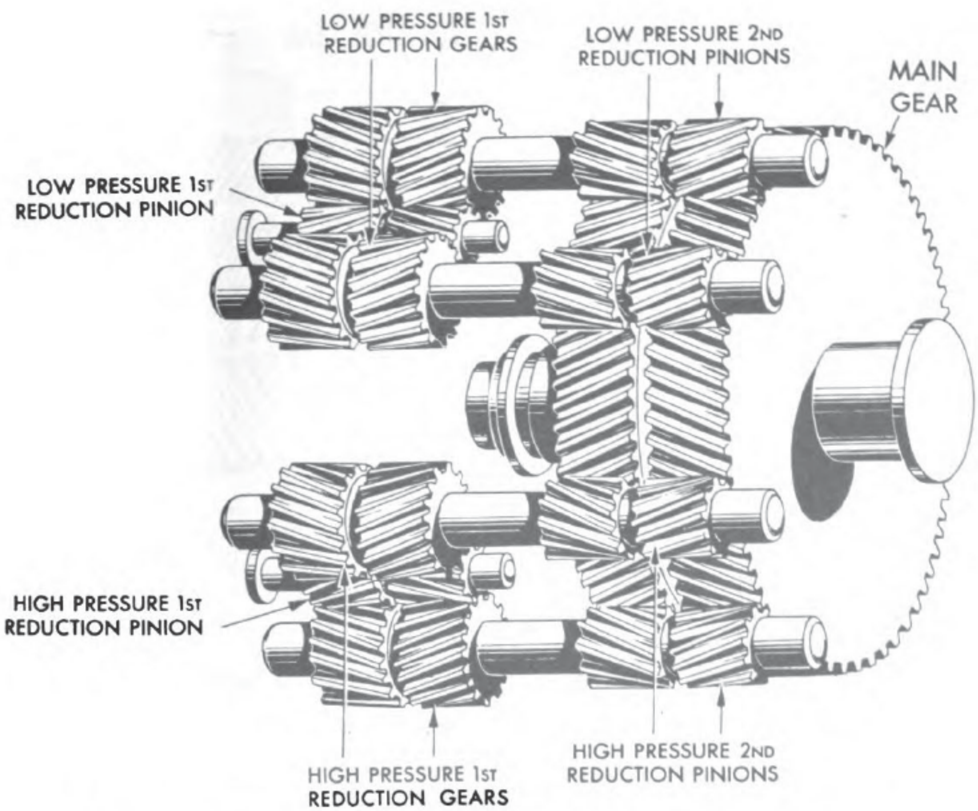


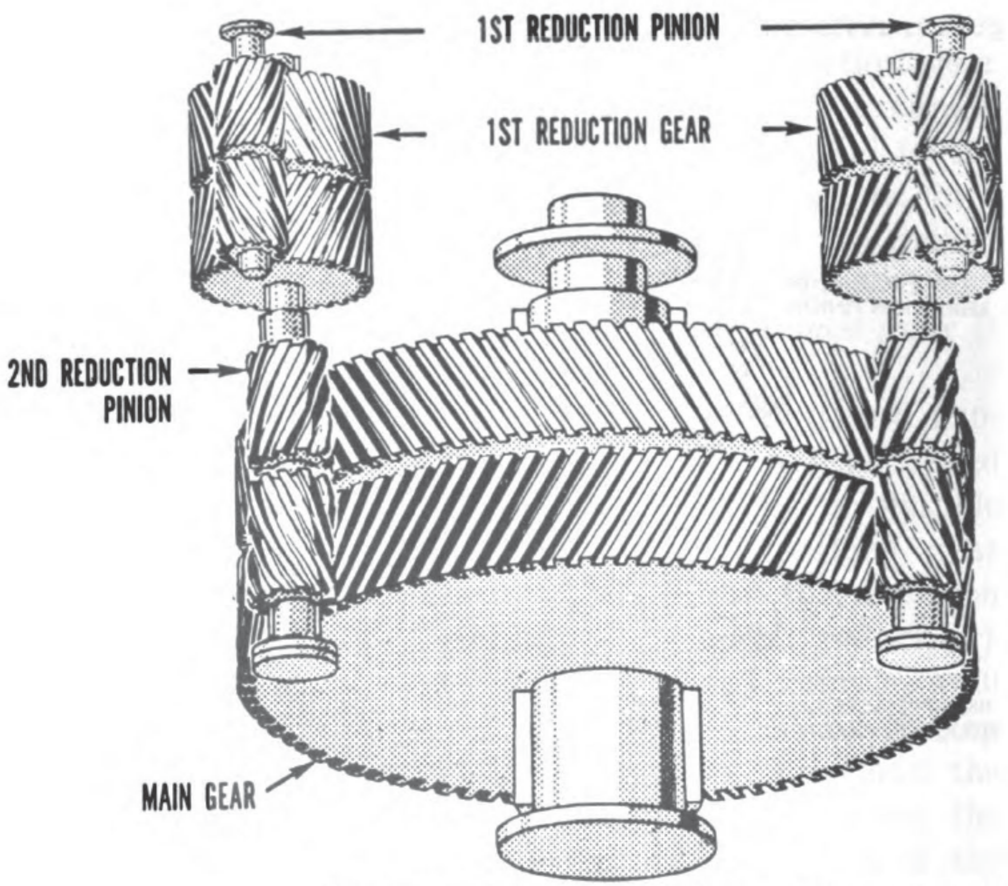
Figure 5–2.—Double reduction gear of a DD 445 class destroyer.

quill shaft and flexible couplings is a second reduction (slow speed) pinion. These four pinions drive the second reduction (or bull) gear which is attached to the propeller shaft.

Types of Double Reduction Gearing

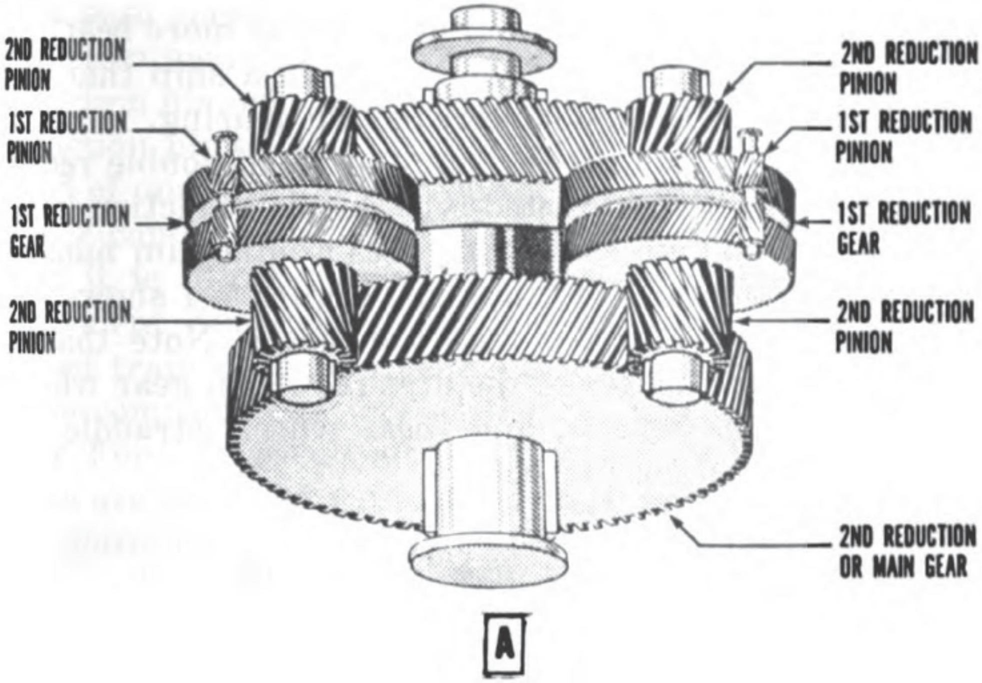
In the previous discussion of double reduction gears, we stated that the DD 692 class destroyers have a LOCKED TRAIN GEARING. There are two other types of double reduction gearing in use—the ARTICULATED GEARING and the NESTED GEARING.

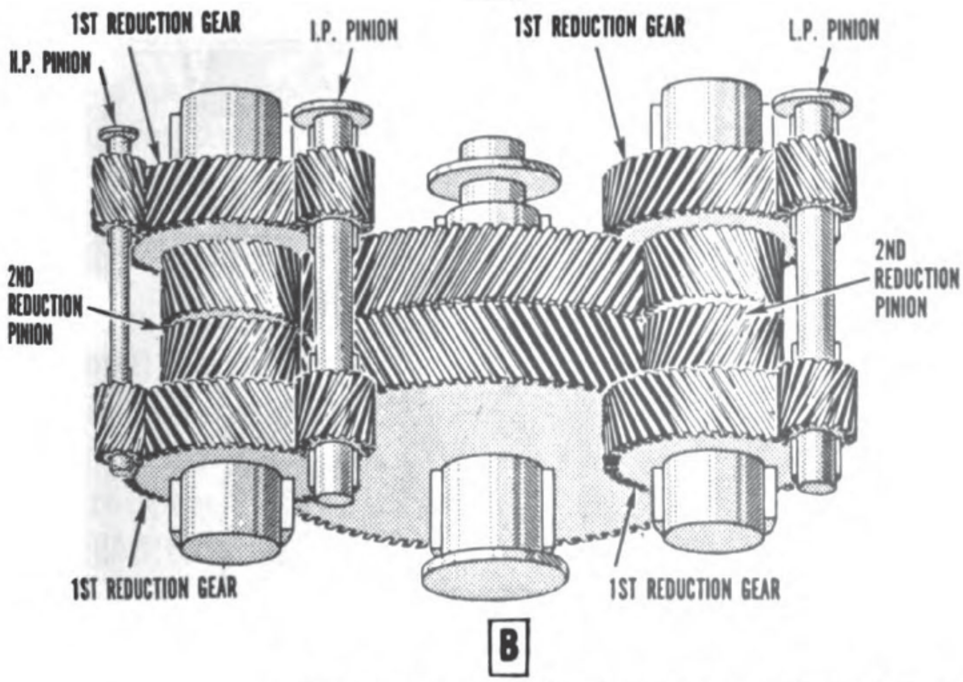
Articulated main reduction gears (fig. 5–3) have two first reduction pinions (high speed), two first reduction gears, two second reduction pinions (slow speed), and a main gear. The first reduction pinions are connected to



Courtesy of Society of Naval Architects and Marine Engineers

Figure 5–3.—Articulated type of double reduction gearing.





Courtesy of Society of Naval Architects and Marine Engineers

Figure 5–4.—(A) Nested-type gearing, with divided main gear. (B) Nested-type gearing with divided first reduction pinion and gear.

the shaft of their respective turbines by means of a special type of flexible shaft and coupling called a QUILL SHAFT. The articulated type of gearing has more bearings and occupies more longitudinal space in a ship than the nested or locked train double reduction gearing.

The nested gearing is the simplest of all double reduction gears (fig. 5–4). Nested-type double reduction gearing employs no quill shafts and uses a minimum number of bearings and flexible couplings. Figure 5–4 shows two different types of nested reduction gears. Note that in figure 5–4B, the helices of the first reduction gear wheels are on separate wheels, and these wheels straddle the second reduction gear wheel.

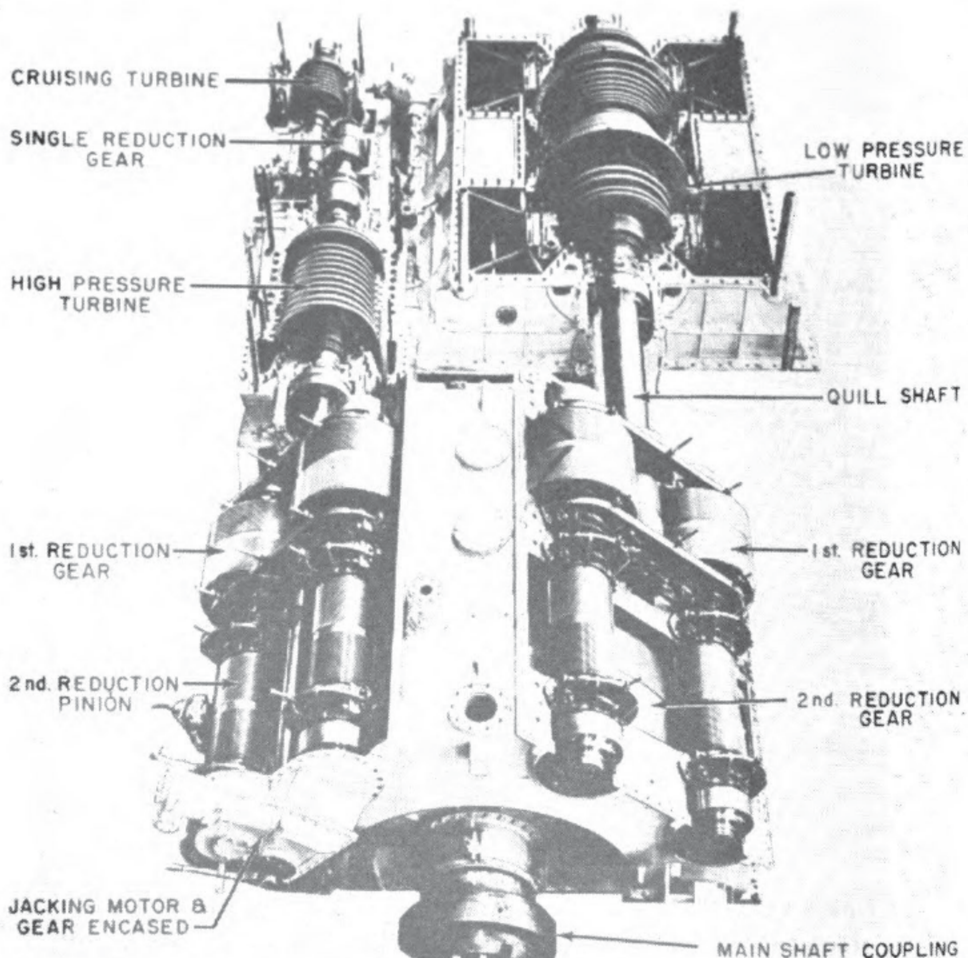


Figure 5–5.—Turbines and locked train double reduction gearing of a combatant ship.

In the locked-train type of double reduction gearing (fig. 5–2), as in turbine driven main reduction gears, each high speed pinion meshes with, or drives, two first reduction gears and thus transmits power to two second reduction pinions. Since the power path between each first reduction pinion and the main gear is split two ways instead of one way, the load on the gear teeth under a given power condition can be designed to be considerably less than it is in other types of main reduction gearing of equivalent dimensions. For a particular power rating, locked train reduction gear units can therefore be made more compact than any of the other types of reduction gear. For this reason, all high powered modern combatant ships are equipped with locked train reduction gears.

Figure 5–5 illustrates a typical turbine and reduction gearing in a combatant ship's engineroom. The size and details will vary for different types of ships, but nearly all ships follow the same general pattern. Note the size of the locked train double reduction gearing for the main turbines as compared to the size of the sing'e reduction gearing for the cruising turbine.

CONSTRUCTION OF MAIN REDUCTION GEARS

The gears in a main reduction gear unit operate at high rotational speed and must be capable of transmitting tremendous power loads. Since even very slight unevenness of tooth contour and tooth spacing would cause the gears to operate noisily or even to fail, special precautions are taken to manufacture the gears to within very close limits. The gears are cut in rooms in which the temperature and humidity are kept constant. Expansion and contraction of the gear-blank, during machining, are negligible, and oxidizing, due to moisture in the air, is virtually eliminated. In addition, all gears are carefully checked as to angularity and each tooth is measured for errors in spacing.

Gear Casings

The gear can be divided into four parts. The lower part is called the base section, or the lower case. It is used to support the bull gear, the main thrust bearing, and the upper parts of the main reduction gear. The intermediate section, called the upper case, supports the bearing housing for the intermediate speed pinions and gears, as well as the high-speed pinions. The other two parts of the gear casing are the main cover sections. The cover sections have inspection ports which are covered by easily operated hinged plates. These ports are so located that the teeth of any pinion or gear can be examined without the necessity of lifting the main cover sections.

Gears

Double helical type gears (fig. 5–1) are capable of transmitting large power loads smoothly, and do not impart axial thrust to either the driving member or the driven member.

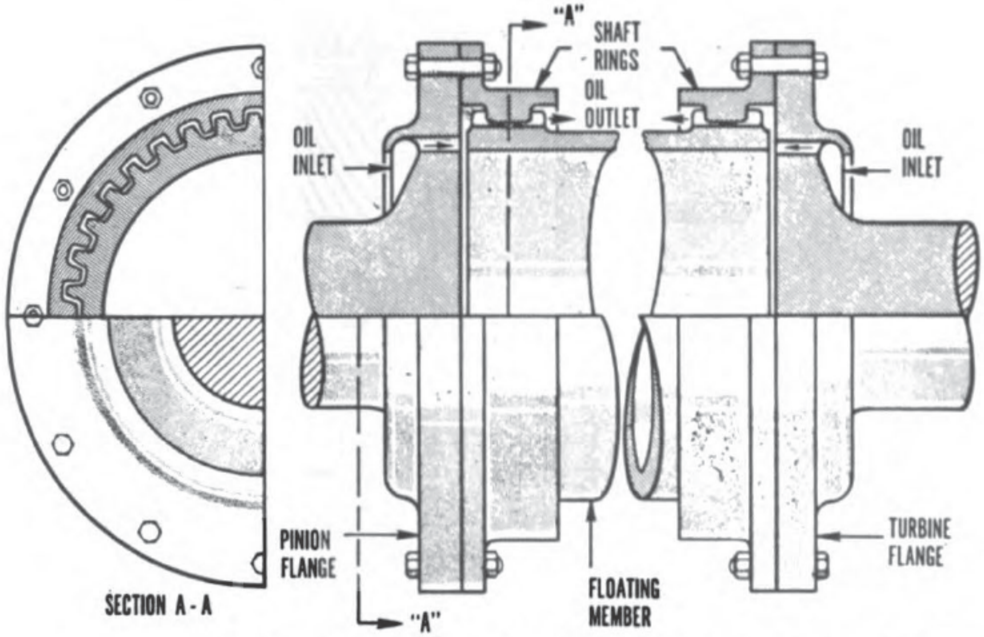
In most cases, all pinions are completely machined out of specially heat-treated nickel-steel forgings. The gear wheels are of built-up construction, with the teeth cut in seamless steel circular bands which are welded to steel spiders. The first reduction gears are generally welded on their respective shafts. The bull gear is usually pressed on the shaft against a locating shaft shoulder, secured by one or more keys and locked, with a locknut, on the shaft.

Flexible Couplings

Flexible couplings provide longitudinal flexibility between the turbine shaft and the pinion gear shaft. This permits each shaft to be readjusted axially in its proper position, and to be held by the thrust bearing of the turbine and the double-helical teeth of the pinion.

In most installations the flexible couplings are of the gear type. Power is transmitted through a floating intermediate member with external teeth that mesh with the internal teeth of the driving and driven shafts.

Figure 5–6 illustrates the design of the gear-type flexible couplings that connect the main turbines to the high-speed pinions of the main reduction gear. The couplings also allow the expansion of the turbine shafts, and take care of any slight misalinement between the main turbines and the reduction gears.

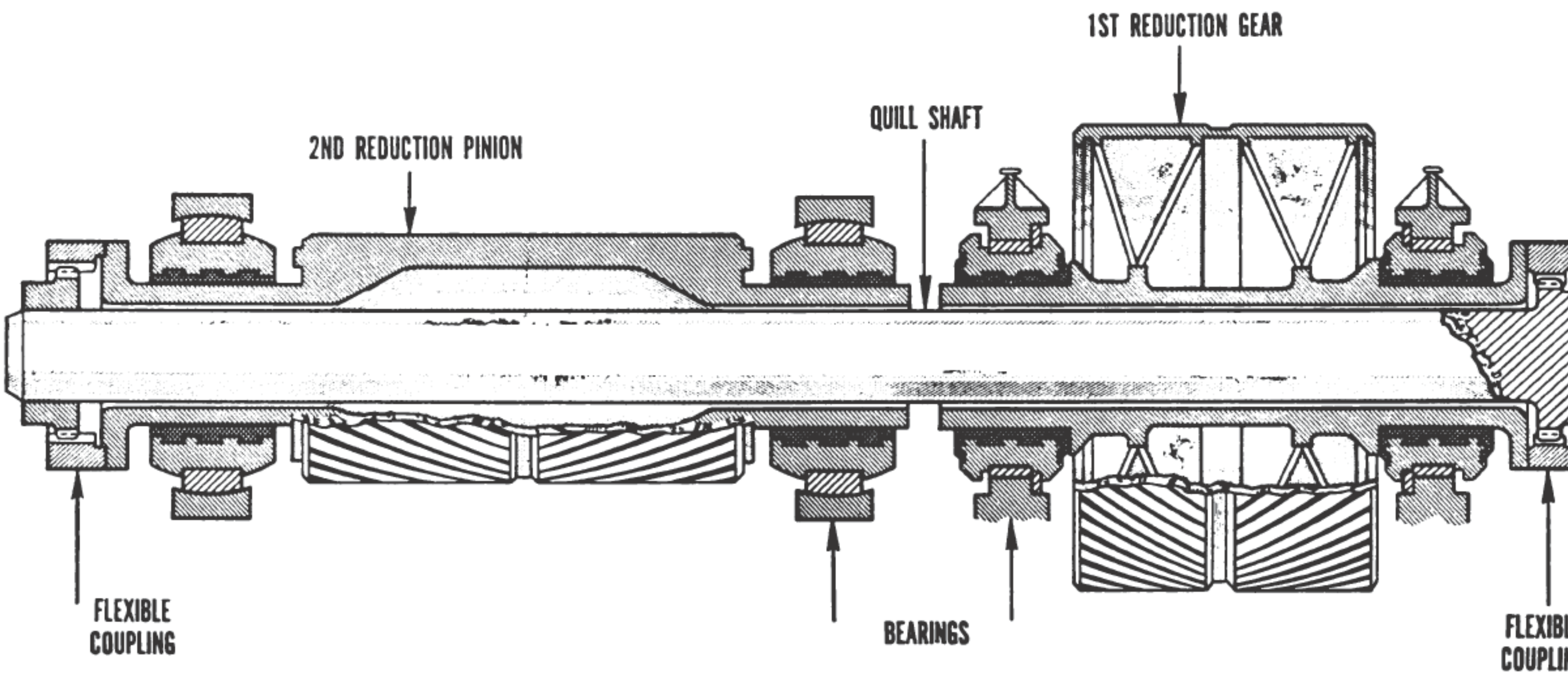


Courtesy of the Society of Naval Architects and Marine Engineers

Figure 5–6.—Gear-type flexible coupling.

The design of the flexible couplings, which connect the first reduction gears and the second reduction pinions, is shown in figure 5–7. In this case, a quill shaft of high torsional flexibility is used, as the floating member, to obtain equal distribution of the load among the several elements of the gear train. The quill shaft runs inside the shafts of the intermediate speed gear and pinion rotors. Figure 5–7 illustrates how flexibility is obtained between the first reduction gear and the second reduction pinion.

A flexible coupling is installed in the shaft between the cruising turbine reduction gear and the high-pressure turbine. Figure 5–8 shows a flexible coupling such as is



Courtesy of the Society of Naval Architects and Marine Engineers

Figure 5-7.—Quill shaft assembly.

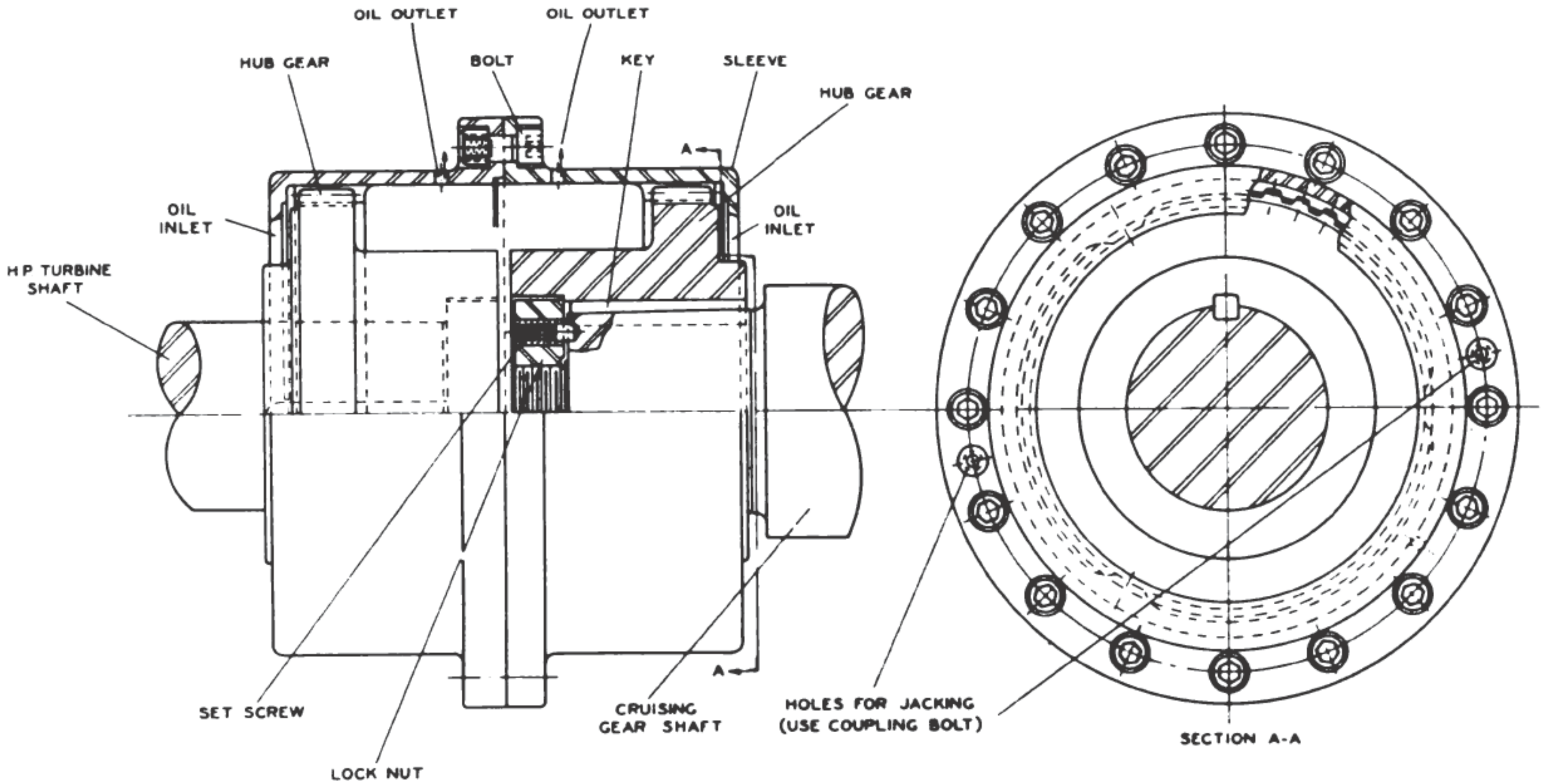


Figure 5–8.—Flexible coupling between the cruising gear and the high-pressure turbine.

used on destroyers. In this coupling, the floating member is a transversely split sleeve, having internal teeth which mesh completely with the external teeth of the spur gears mounted on the connected shaft ends.

Steady streams of oil from the supply passages of adjacent bearings are directed into the coupling when the reduction gears operate. The oil is caught by projecting lips of the turbine and pinion flanges (see fig. 5–6). Centrifugal action forces oil through the horizontal holes in the flanges to the coupling teeth. Oil is discharged from the teeth into coupling guards and then flows into the oil drain system.

Jacking Gear

All geared turbine installations are equipped with an electric motor-driven jacking or turning gear. A typical jacking mechanism is illustrated in figure 5–9. The unit is used for turning the main engine during warming up and securing periods so that the turbine rotor may heat or cool evenly. (The rotor of a hot turbine or of one that is in the process of being warmed up, with gland sealing steam cut in, will become bowed or distorted if left stationary even for a few minutes.) The jacking gear is used for other routine purposes such as for turning the engine in order to bring the reduction gear teeth into view during routine inspection. In addition, the jacking gear is used for the required daily jacking of the main gear (1¼ revolutions).

Generally, the jacking mechanism is mounted on top and near the after end of the main reduction gear casing, in line with the high-pressure first reduction pinion. It usually consists of an electric motor, at least one set of worm gears, and sets of spur gears or helical gears. A typical jacking gear is shown in figure 5–9. A manually operated jaw type clutch forms the connection between the jacking gear and the main pinion when the jacking gear is in use. Reduction ratios as high as 16,000 to 1 between the propeller and turning gear motor are used;

therefore, if the propeller were allowed to turn at 1 rpm, the turning gear motor would be overspeeded and seriously damaged.

Because of the high gear ratio, it is possible to use the jacking gear, in conjunction with a friction brake provided on the gear, to hold the propeller shaft of an engine from turning while the ship is steaming on its other

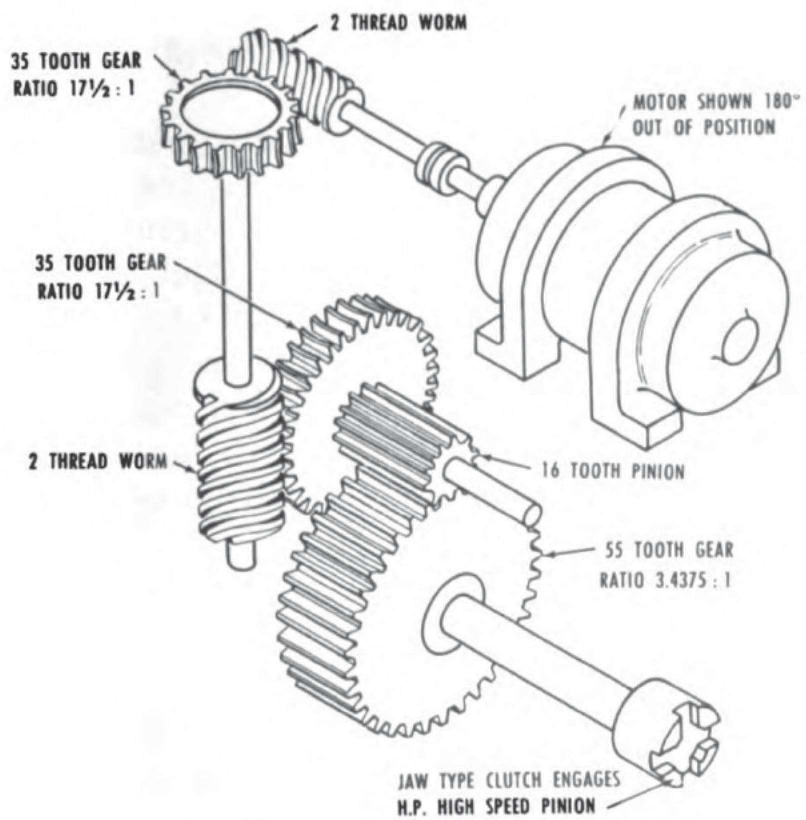


Figure 5–9.—Jacking gear mechanism.

engines. To lock a shaft by means of the jacking gear, it is first necessary to stop the shaft, either by admitting steam to the astern turbine to balance the turning action resulting from propeller drag while the ship is under way, or by stopping the ship. Once the propeller shaft is stopped, the jacking gear can be engaged and the friction brake applied and tightened.

REDUCTION GEARS FOR AUXILIARY MACHINERY

In this discussion of reduction gears for auxiliary machinery, let us first consider some of the ship's service turbine-generators in current use. In the 300-kw Type MPC–6, 240/120-volt turbine-generator (fig. 5–10). The reduction gear is of the single-reduction, single-helical type. A gear ratio of 8.3433 to 1 reduces the turbine speed of 10012 rpm to the generator speed of 1200 rpm. The axial position of the turbine rotor and pinion is maintained by a high-speed thrust bearing mounted on the generator end of the pinion shaft.

Let us now consider the reduction gear used on a turbine-driven main circulating pump and a main condensate pump. Turbine-driven main circulating pumps (fig. 5–11) use a single reduction, double-helical type reduction gear. A gear ratio of about 8 to 1 reduces the turbine speed of some 5000 rpm to the pump speed of 600 rpm. Lubrication of the reduction gear is provided by a gear-type pump mounted on the lower end of the pinion shaft. Oil is sprayed through an orifice into the space between the gear teeth.

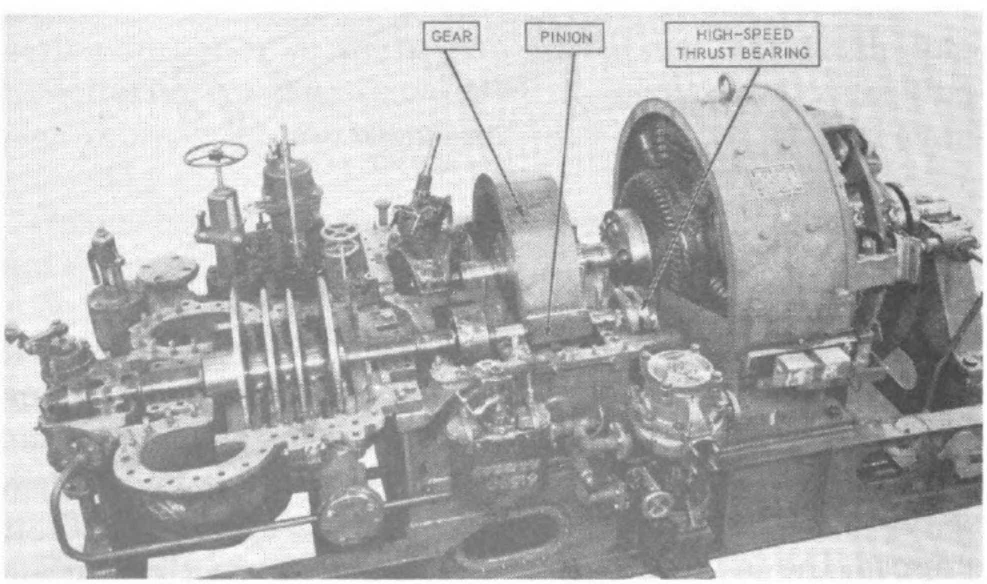


Figure 5–10.—300-kw turbine-generator showing reduction gearing.

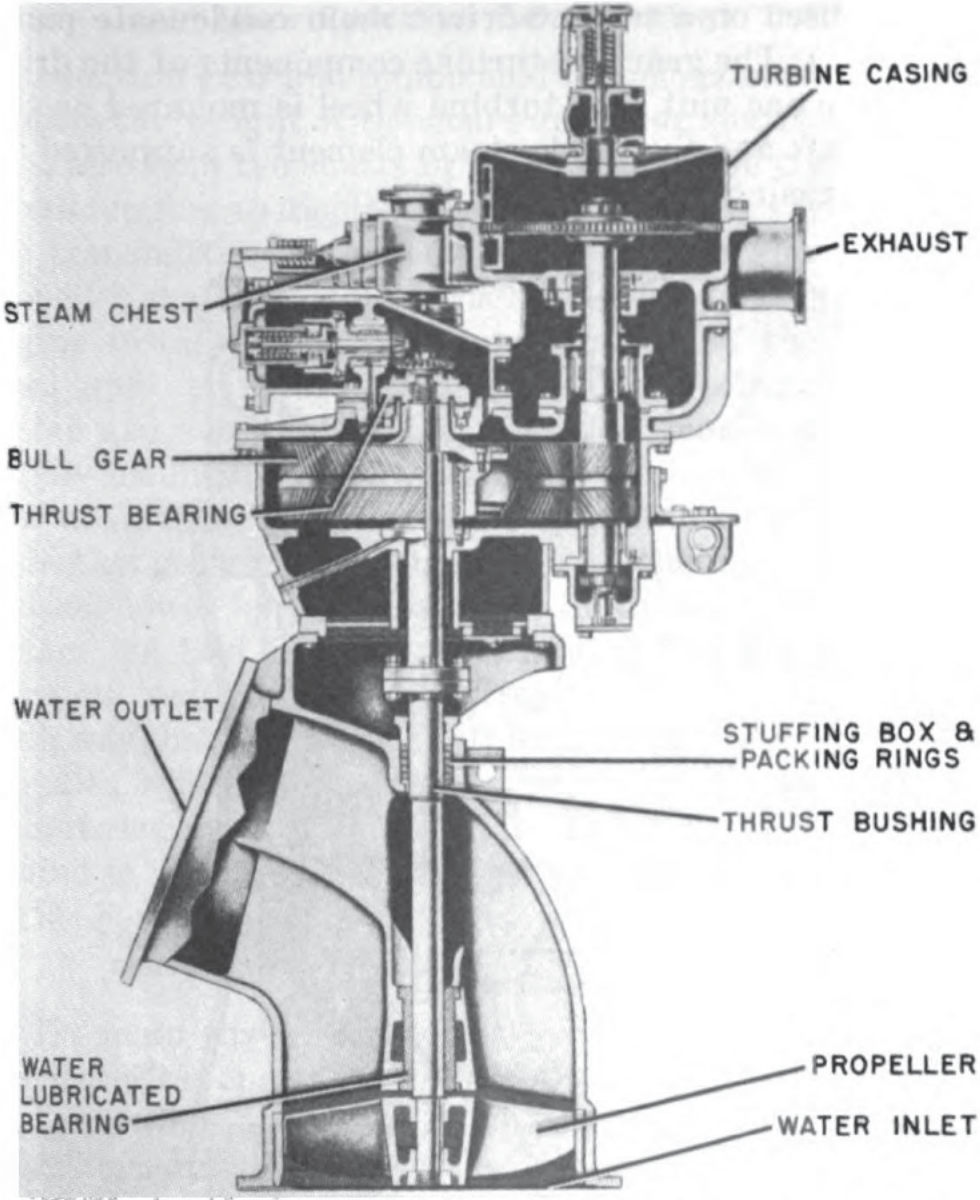


Figure 5-11.—Main condenser circulating pump (showing reduction gearing).

The weight of the combined rotating element of the pump and the driving unit is carried on a Kingsbury-type thrust bearing which supports a collar mounted at the upper end of the reduction-gear shaft. The weight of the turbine rotor and pinion shaft is transmitted to the Kingsbury thrust bearing through the teeth of the double-helical reduction gear.

For our second example, let us consider the reduction

gearing used on a turbine-driven main condensate pump (fig. 5–12). The gear and turbine components of the drive constitute one unit. The turbine wheel is mounted on the worm shaft and the whole steam element is supported by the gear casing.

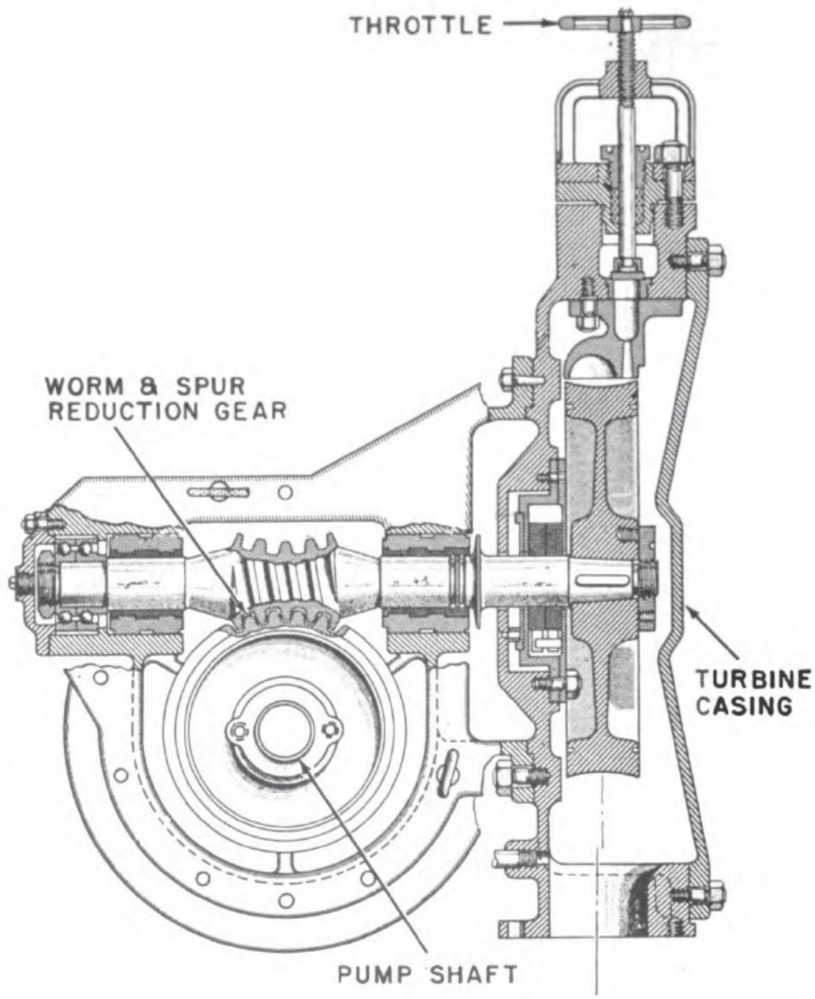


Figure 5–12.—Main condensate pump reduction gearing.

The main drive gears are of the single-speed reduction, straight worm type, having a speed ratio of $4\frac{5}{6}$ to 1. The worm wheel shaft mounts the pinion of the helical gears used for the governor and lubricating oil pump drive. The worm shaft is carried in two sleeve bearings and located axially by thrust bearings while the low-speed shaft is mounted in ball bearings.

Main Reduction Gear Bearings

Reduction gear and pinion shaft bearings must not only support the weight of the gears and their shafts, but they must also hold the shafts in place against the tremendous forces tending to displace the shafts and gears when they are transmitting power from the turbine shaft to the propeller shaft. Like other radial sleeve bearings in main engine installations, these bearings are of the babbitt-lined split type; however, instead of being spherical seated and self-alining, the reduction gear bearings are rigidly mounted and dowelled into the bearing housings. The angular direction of the forces acting upon a main reduction gear bearing changes with the amount of propulsion power being transmitted by the gear. In order to obtain the best bearing performance when load is the greatest, reduction gear bearings must be positioned in such way that the heavy shaft load is not brought against the area where the bearing halves meet (the split). For this reason most of the bearings in a reduction gear are placed so that the split between the halves is at an angle to the horizontal plane.

Main Thrust Bearing

The main thrust bearing is located either at the forward or after end of the main reduction bull gear or in the propeller line shafting aft of the gear. The purpose of the main thrust bearing is to absorb the thrust imparted to the propeller shaft by the propeller. Since the amount of thrust involved is actually the force that the propeller generates in pushing the ship through the water, the main thrust bearing on each propeller shaft must be large and rugged.

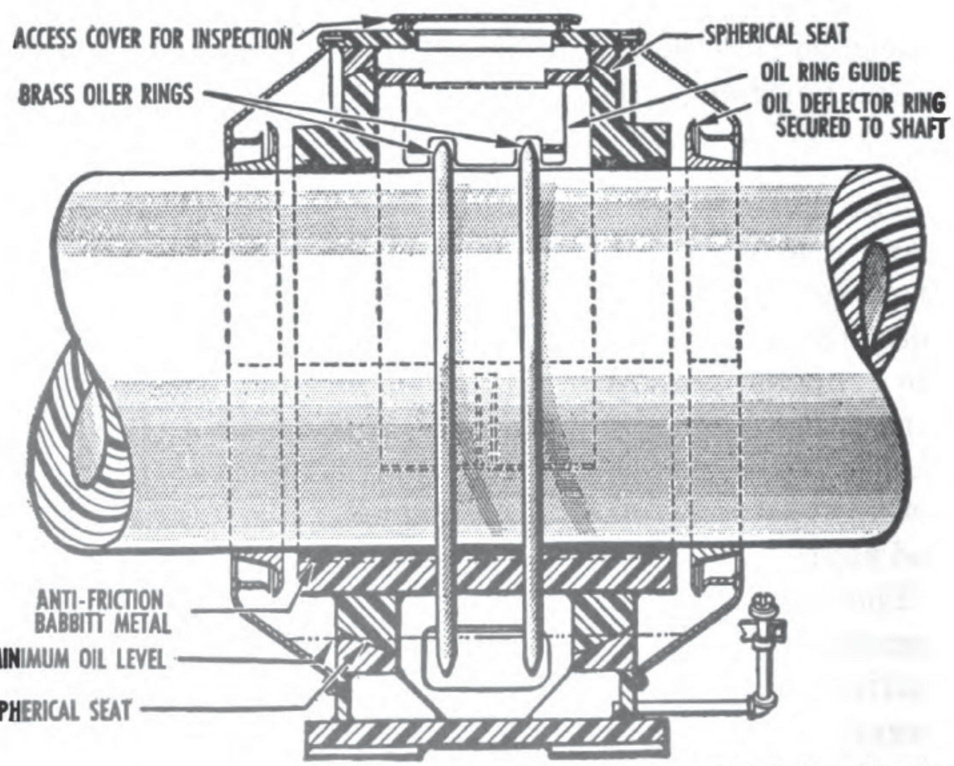
The conventional thrust bearing in naval use is the segmented pivoted shoe similar to the turbine thrust bearing, described in chapter 4 of this book, but much larger.

Lubrication of the main thrust bearing is provided by the same system which furnishes oil to the turbine bear-

ings, reduction gears, and flexible couplings—if located in with the reduction gear. If the main thrust bearing is located in the shaft alley, then lubrication of the bearing differs. Oil is taken from the main thrust sump by either an electric-driven gear-type pump or a chain-driven gear-type pump. In addition, these pumps have their own cooling system—making use of sea water from the fire main for cooling the oil to the thrust bearing.

Main Propulsion Shaft Bearings

In this section we shall consider the main propeller shaft bearings which you will also be required to watch carefully and to maintain. The bearings which support and hold the propulsion shafting in alinement are divided into two general groups: the main line shaft bearings or spring bearings, and the stern tube bearings and the strut bearing.



Courtesy of U. S. Naval Institute

Figure 5–13.—Diagram of a main line shaft bearing.

Main line shaft bearings or spring bearings.—These bearings are of the ring-oiled, babbitt-faced, spherical seat shell-type bearings. This bearing, illustrated diagrammatically in figure 5–13, is designed primarily to aline itself to support the weight of the shafting. In many of the older, low-powered ships, the bearing is not of the self-alining type and consists only of a bottom half. The upper half of the assembly consists only of a cap or cover (not in contact with the shaft) to protect the shaft journal from dirt. The spring bearings of all modern naval ships, however, are provided with both upper and lower self-alining bearing halves.

The brass oiler rings, shown in figure 5–14B, hang loosely over the shaft journal and the lower bearing half, and are slowly dragged around by the rotation of the shaft. As they glide through the reservoir of oil at the bottom the rings carry some of the oil along to the top of the shaft journal. The upper bearing half is grooved to accommodate the rings. Disks and roller chains are sometimes used instead of the brass rings.

For further discussion of ring-oiled spring bearings, refer to chapter 6 on Lubrication.

Stern tube and stern tube bearings.—The hole in the hull structure for accommodating the propeller shaft to the outside of the hull is called the stern tube. The propeller shaft is supported in the stern by two bearings, one at each of the inner and outer ends of the stern tube, and are called stern tube bearings. At the inner end of the stern tube is a stuffing box packing gland (fig. 5–15) generally referred to as the stern tube gland. The stern tube gland seals the area between the shaft and stern tube and yet allows the shaft to rotate. Construction of the stern tube bearings is similar to that of the strut bearings which are described later in this chapter.

The stuffing box is flanged and bolted to the stern tube. Its casting is divided into two annular compartments—the forward space being the stuffing box proper, the after

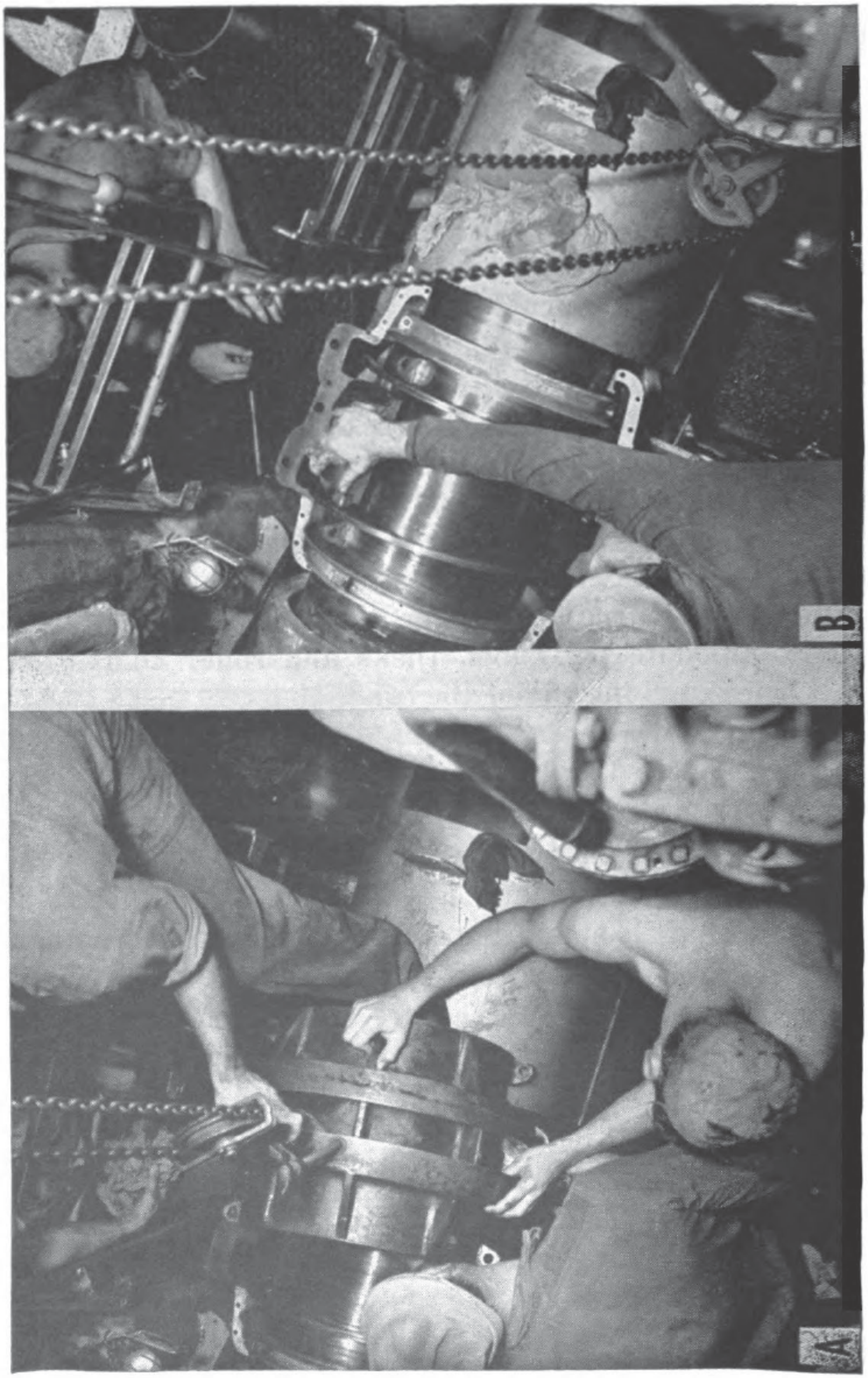
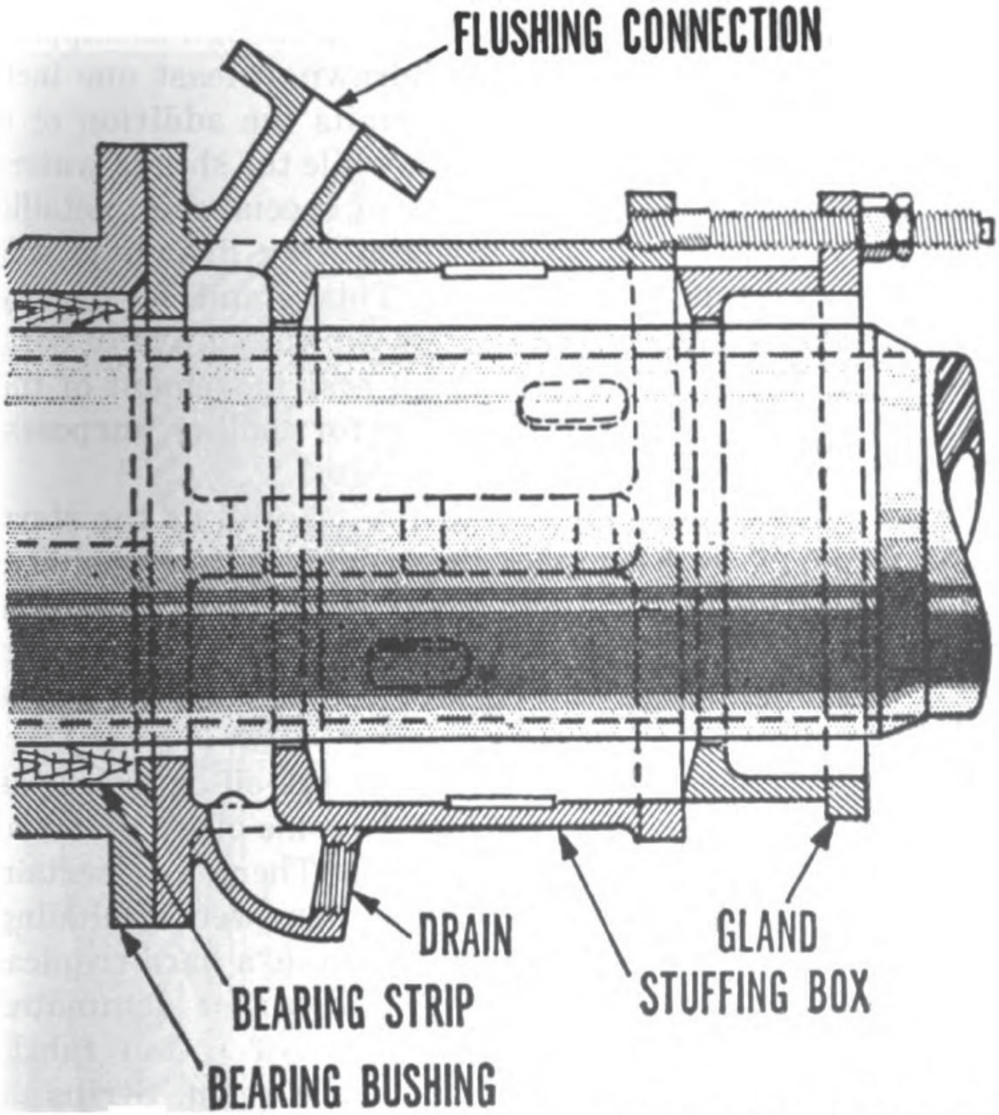


Figure 5–14.—Removing a main line shaft bearing. (A) Removing the upper half. (B) Removing the lower half.



Courtesy of U. S. Naval Institute

Figure 5–15.—Stern tube stuffing box and gland.

space being provided with a flushing connection for providing a positive flow of water through the stern tube for lubricating, cooling, and flushing. This flushing connection is supplied by the fire main and flushing system. A DRAIN CONNECTION is provided both for testing the presence of cooling water in the bearing, and for permitting sea water to flow through the stern tube and cool the bearing when under way, where natural sea water circulation is employed.

The gland for the stuffing box is divided longitudinally

into two parts. The gland bolts are long enough to support the gland when the latter is withdrawn at least one inch clear of the stuffing box. This permits the addition of a ring of new packing, when needed, while the ship is waterborne. Either braided flax packing or special semimetallic packing is used (your ship's engineering drawings will tell you the type of packing). This gland is usually tightened up to eliminate leakage when the ship is in port, and loosened just enough to permit easy movement of the shaft, and a slight trickle of water for cooling purposes, when the ship is under way.

STRUT BEARINGS.—These bearings, as well as the stern tube bearings, are equipped with composition bushings which are split longitudinally into two halves. The outer surface of the bushing is machined with steps to bear on matching landings in the bore of the strut. One end is bolted to the strut.

Since it is usually impracticable to use oil or grease as a lubricant for underwater bearings, some other material must be employed for that purpose. There are certain materials that become slippery when wet, including natural or synthetic rubber; lignum vitae, a hard tropical wood with excellent wearing qualities; or laminated phenolic material consisting of layers of cotton fabric impregnated and bonded with phenolic resin. Strips of this material, as shown in figure 5–16, are fitted inside the bearing bushing.

A rubber composition is the type most used in modern installations. These bearings, of course, will never be seen by you while the ship is afloat, and chances are you will have little to do with them when your ship is in dry dock, as then the yard men will be doing most of the work.

MAIN PROPULSION SHAFTING

The turbine and reduction gears convert the thermal energy of steam into usable mechanical energy. This mechanical energy is utilized through the propulsion

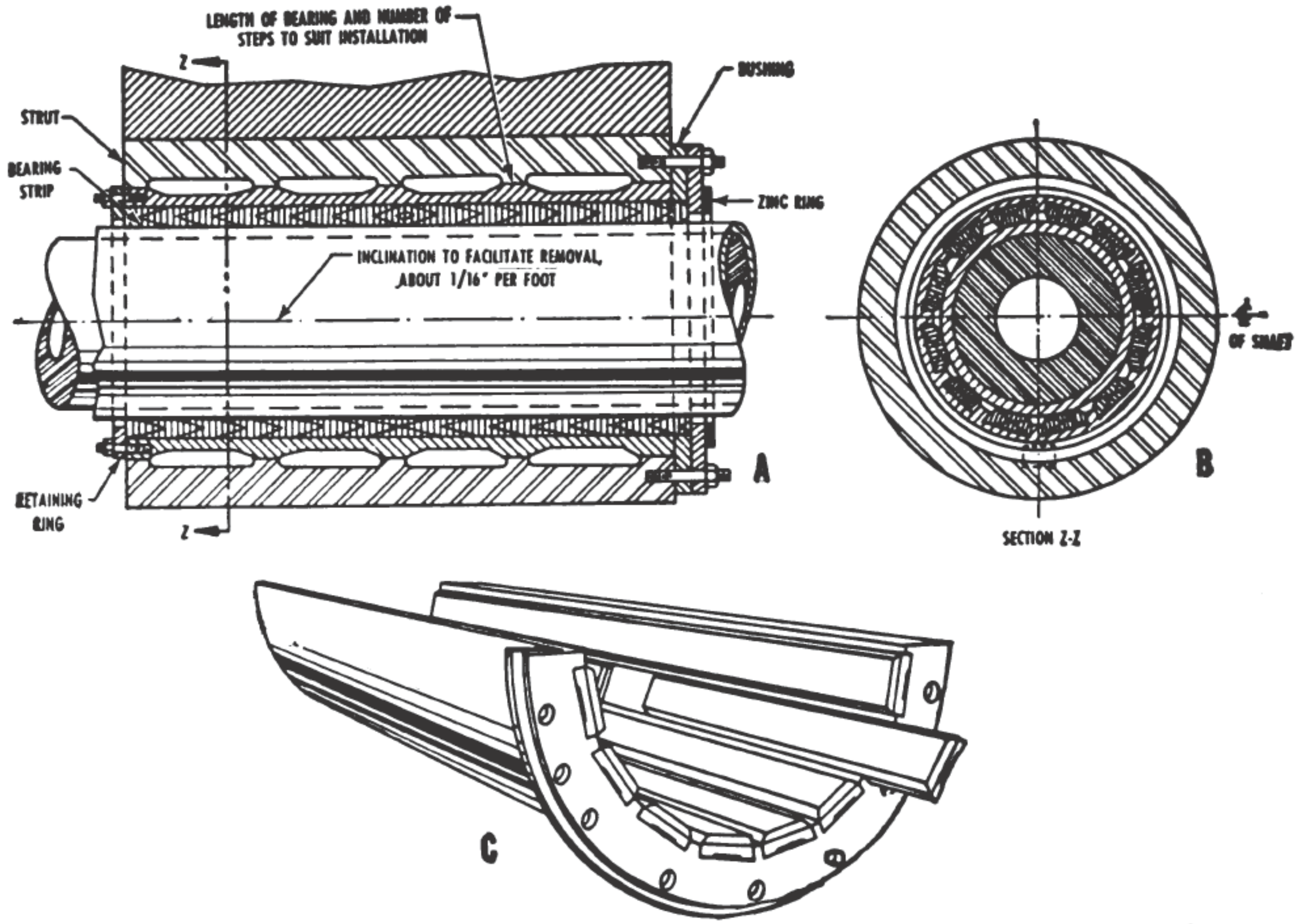


Figure 5–16.—Details of underwater strut bearing. (A) Longitudinal view. (B) Cross-sectional view. (C) Rubber stripping in the bearing bushing.

shafting and the propeller. The MAIN PROPULSION SHAFTING itself, which ranges in diameter from 18 to 21 inches from small twin-screw destroyers to approximately 30 inches for large four-screw carriers, is divided into four functional sections—the line shaft, thrust shaft, stern tube shaft, and propeller or tail shaft (fig. 5–17).

Segments of the line and thrust shaft sections of the shafting are joined together with integral FLANGE TYPE COUPLINGS. The stern tube shaft is joined to the after end of the line shaft with what is known as the INBOARD STERN TUBE COUPLING, with a removable after-sleeve flange. The tail shaft is joined to the stern tube shaft with what is known as a MUFF TYPE OUTBOARD COUPLING. The shaft bearings have already been discussed in a preceding section.

On single screw ships, that portion of the outboard shaft which turns in the stern tube bearing is normally covered with a SHRUNK-ON COMPOSITION SLEEVE. This is done to protect the shaft from corrosion, and to provide a suitable journal for the water lubricated bearings. On multiple-screw ships, these sleeves normally cover only the bearing areas, and the exposed shafting between the sleeves is covered with synthetic sheet rubber to protect it against sea water corrosion.

For carriers, cruisers, and battleships, normally the wet shafting (shafting outboard in the sea) is composed of three sections, a tail shaft, an intermediate or drop-out section, and a stern tube section. Integral flanged ends of these sections are normally used for joining sections together.

Circular plate-steel, or composition shields known as FAIRWATERS, are secured to the bearing bushings of the stern-tube and strut bearings, and to both the forward and after ends of the underwater outboard couplings. These are intended, primarily, to reduce underwater resistance. The coupling fairwaters are secured to both the shaft and coupling flanges, and are filled with tallow to protect the coupling from corrosion.

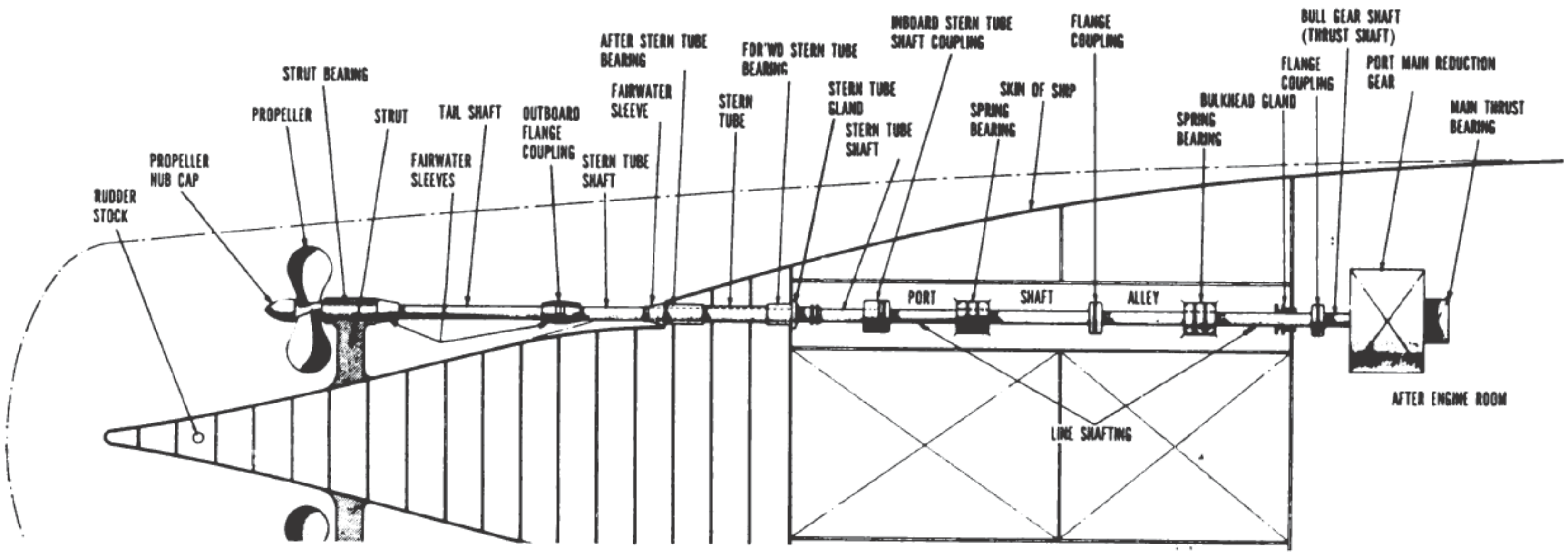


Figure 5–17.—Diagrammatic arrangement of a main propulsion shafting.

SHIP'S PROPELLERS

The screw propellers, where the mechanical energy produced by the main engine is finally utilized, are of various types of construction. They may be LEFT-HAND HELICES, turning counterclockwise in ahead direction when viewed from astern, or RIGHT-HAND HELICES, turning clockwise. All starboard and center-line propellers turn clockwise. All port propellers turn counterclockwise. They may be of CONSTANT PITCH, with pitch of blades identical at all points along the radius; VARIABLE PITCH, with pitch of blades varying along the radius; or CONTROLLABLE PITCH, with blades capable of being rotated within their sockets to change speed and direction of propeller thrust. They may be of SOLID CONSTRUCTION, of SINGLE CASTING, or of BUILT-UP CONSTRUCTION, with individually cast blades bolted to the propeller hub. The number of blades may vary from three to five.

MAIN REDUCTION GEAR CARE AND OPERATION

1. LUBRICATION.—Efficient lubrication of reduction gears is of utmost importance. Oil at the designated working pressure and temperature must be supplied to the gears at all times while they are being turned over, either with or without load. Lubricating oil, Navy symbol 2190T is used for the main reduction gears as well as for the turbines. Clean, pure oil is essential if long life and successful operation of the gear is desired.

Oil must be free from all impurities—especially such impurities as water, dirt, grit, and metallic particles. Care must be taken to remove metal flakes and fine chips as new gears are being worn into a working fit. Lint or dirt, if allowed to remain in the system, will clog the oil-spray nozzles that lubricate the gears. Keep oil-spray nozzles open at all times. Never alter the oil-spray apparatus without proper authority.

Fine metallic particles which are not picked up by the magnets in the lube-oil strainers, or dirt which may get

through the strainers, may become embedded in the babbitted bearings and eventually score the journals. In addition, the mixture of dirt and metallic particles may erode metal from the gear teeth surfaces. The solution to this problem calls for clean, purified oil.

2. EFFECTS OF ACID AND WATER IN OIL.—Water in the oil is extremely dangerous. Even small amounts soon cause pitting and corrosion of the teeth. Acid is equally dangerous. The oil must be tested frequently for water as well as for acid content.

Corrective measures must be taken when salt water is found in the reduction gear lubricating oil system. Occasionally gross contamination of the oil by salt water occurs when a cooler leaks or when leaks develop in a sump which is integral with the skin of the ship.

Immediate location and sealing of the leak or removal of the source is not enough. Steps must also be taken to remove the contaminated oil from all steel parts and surfaces. Postponement of such treatment may cause badly corroded and pitted gears, journals, and couplings, in addition to burned-out bearings.

When the main engines are secured, the oil should be circulated until the temperature of the oil and of the reduction gear casing approximates the ultimate engine-room temperature that will be attained. While the oil is circulated, the cooler should be operated and the engine should be jacked continuously. The purifier should also be operated while the oil is being circulated, and after circulation until water is no longer discharged from the purifier. This procedure will eliminate condensation from the interior of the main reduction gear casing.

3. SUMP OIL LEVEL.—Since the reduction gears are located directly above the lubricating oil sump tank, positive means should be taken to ensure that the bull gear wheel will not dip into the oil. The proper oil level in the sump is indicated by a liquid level indicator. This oil level indicator registers two indications—normal level and low level. If the bull gear is permitted to rotate in the oil, the

churning action will aerate the oil and cause the oil temperature to rise. This condition can be noted by an overflow of foaming oil from the escape vent in the top of the gear casing. If this occurs, the engines must be slowed or stopped until the excess oil can be removed and normal conditions restored.

4. UNUSUAL SOUNDS.—A properly operating reduction gear has a certain definite sound. Any unusual noises from the reduction gears should be investigated. The gears should be operated with caution until the cause is discovered and remedied.

BEARING PREVENTIVE MAINTENANCE

1. LUBRICATION.—An oil film must always be maintained between a bearing and its journal and the heat generated by friction must be removed. Satisfactory bearing performance will be ensured if the oil film is maintained. Most bearing trouble arises from neglect of proper lubrication, dirty oil, or obstructions in the oil piping to the bearings.

2. RUNNING HEAT OF BEARING.—Within limits, there is no objection to the rise in temperature of a running bearing; in fact it must take place. The rise in temperature is advantageous in that it is accompanied by a decrease in the viscosity of the lubricant. This decreases the internal friction at any given speed. There is no objection to running a bearing warm provided the temperature reached is not sufficient to do harm, and provided there is no progressive increase in heat, indicating trouble. The thing to guard against is not necessarily a high running temperature of a bearing, but rather a rapid rise in temperature and an increase over the usual operating temperature of the bearing.

If the temperature of a bearing increases above its normal running temperature, the quality and quantity of the lubricant supplied to the bearing should be checked first. If possible increase the supply of lubricant to the

bearing. In addition, increase the flow of circulating water to the coolers. If these measures do not reduce the bearing temperature, the speed of the unit should be reduced or the unit should be stopped.

3. WIPED BEARINGS.—Once a bearing has wiped, it should be reconditioned at the first opportunity. If it has wiped but slightly, it probably can be scraped to a good bearing surface and restored to service. However, if the bearing is wiped badly or burned out, the bearing must be replaced.

QUIZ

1. How is high turbine shaft rpm stepped down so that the propeller can function efficiently in a lower rpm range?
2. What is the function of the gears in a reduction gear?
3. How is the operational efficiency increased in both turbines and propellers?
4. What type of reduction gear is used on all modern combatant ships?
5. What type of gears are most often used in current reduction gears?
6. In a reduction gear, why are helical gears preferable to spur gears?
7. If a ship is not under steam, and not in dry dock, how often and how much should the main shaft be jacked over?
8. Where can a main thrust bearing be located?
9. If a main thrust bearing is located in the shaft alley, how is the bearing lubricated?
10. What type of thrust bearing is commonly used on naval vessels?
11. How are main line shaft spring bearings lubricated?
12. What is the purpose of the stuffing box and packing gland at the inboard end of the stern tube bearing?
13. What type of bushings are used on strut bearings?
14. With regard to pitch of the blades, what three varieties of screw propellers are used on naval vessels?
15. What is the effect of a high oil level in the reduction gear sump?
16. What are the common causes of bearing trouble?
17. Which of the Navy lubricating oils is used for the main reduction gearing?

CHAPTER 6

LUBRICATION

Too much emphasis cannot be placed on the importance of proper lubrication of all units in any machinery plant. All moving surfaces must receive a steady and adequate oil supply of proper quality at the correct temperature and free of any extraneous matter. In addition, a means must be provided for removing impurities from the lubrication system and for maintaining a reserve supply of good clean oil (lubricant).

PRINCIPLES OF LUBRICATION

To understand the principles of lubrication you should know the purposes of a lubricant. Lubricants reduce friction between moving parts. Oil also acts as an internal cooling and cleansing agent and as a cushioning medium between metal surfaces. Some authorities claim that oil in a diesel engine also acts as a sealant in the cylinders to prevent blowby.

Types of Friction

As previously stated, the primary purpose of a lubricant is to reduce friction between moving surfaces. FRICTION may be defined as the resistance to motion offered by the surfaces of two bodies in contact. When this frictional resistance is overcome, and motion takes place, heat is generated. There are three kinds of friction:

1. SLIDING FRICTION—between two solids whose opposing surfaces slide over each other.
2. ROLLING FRICTION—between two solids, one (or both) of which is rolling on the other.
3. FLUID FRICTION—between the molecules or particles of a fluid, or between two films of fluid.

Since liquid lubricants can be readily circulated, they are universally used for internal lubrication. Lubricating oils are mineral oils obtained from petroleum. In theory, fluid lubrication is based on the actual separation of the surfaces so that no metal-to-metal contact occurs. As long as an oil film remains unbroken, sliding or rolling friction is replaced by the fluid friction (internal friction) of the lubricant itself. Under such ideal conditions, friction and wear are held to a minimum.

Purpose of Lubrication

The primary purpose of lubricating oil and grease is to substitute fluid friction for either of the other two types of friction. This means that a lubricant of sufficient quantity and consistency must be provided to keep the moving metal parts (of bearing, lining, and journal, for example) from contacting each other. The remaining fluid friction, within the lubricant itself, is far less than that which would otherwise occur between the solids, but it, too, generates heat which must be removed.

This brings you to the secondary but highly important purpose of a lubricant, that of ABSORBING AND REMOVING THE HEAT which is generated by the fluid friction and the heat which, in cases of steam turbines, is conducted along the shafting from the steam-heated rotors. The removal of this heat by the lube oil prevents serious damage to the machinery parts and makes it necessary to have the oil repeatedly cooled as it circulates about the mechanisms.

In general, BOTH FRICTION AND OPERATING TEMPERATURES in bearings increase with a greater unit bearing pressure; with thinner films of the lubricant, if below a definite minimum; with a high velocity of rubbing or

rotation of the journal; and with a higher viscosity of the lubricant.

Oil Film Lubrication

The present accepted theory of lubrication is based upon the action of fluid films of oil between two surfaces, one or both of which are in motion. In theory there are three or more layers or films of oil existing between the two surfaces of a bearing. There are two BOUNDARY FILMS (film layers I and V in fig. 6–1), one of which clings to

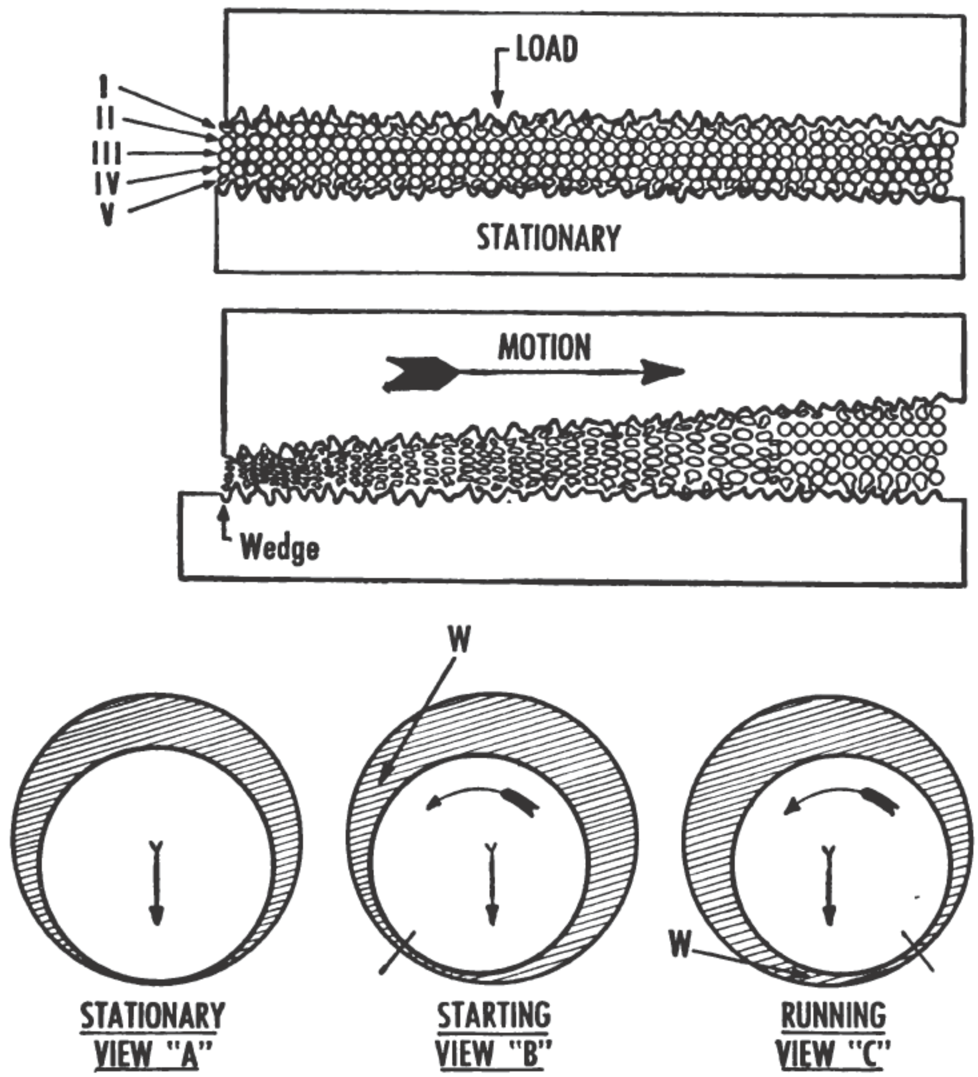


Figure 6–1.—Oil film lubrication (schematic diagram): (A) stationary position, showing several oil films; (B) surface set in motion, showing principle of oil wedge; (C) principle of A and B shown in a journal bearing.

the surface of the rotating journal, and one of which clings to the stationary lining of the bearing. Between these two boundary films are one or more FLUID FILMS (II, and III, and IV in fig. 6–1). The five molecular films of oil shown in the illustration are arbitrarily chosen for purposes of explanation.

When the rotating journal is set in motion (fig. 6–1B), its surface is set at an angle to the surface of the bearing lining, and forms a wedge of oil that prevents surface contact. The oil films II, III, and IV then begin to slide between the two boundary films, and thus continuously PREVENT CONTACT OF THE SURFACES. The principle is again illustrated in figure 6–1C, where the position of the oil wedge W is shown with respect to the position of the journal as it starts and continues in motion.

If the conditions are correct, the two surfaces are effectively separated, except for a possible momentary contact at the time the motion is started. Among the most important CONDITIONS DETERMINING THE EFFICIENCY of an oil film are the alignments, the lack of distorted surfaces, and the running clearances between the bearing and the journal. These clearances are correlated to the amount and viscosity of the lube oil passing through the clearance area. The efficiency is contingent upon a number of other conditions as well.

LUBRICATING OILS

There are a number of things you should know about lubricating oils. You should know what types exist, some of the principal characteristics which determine their quality, the meanings of Navy lube oil symbols, and exactly which oil to use for each lube oil requirement.

Types of Lube Oils

There are two general types of lubricating oils—the mineral type, and the compound or additive type. The MINERAL TYPE OILS are petroleum oils derived from crude

oil, and are used in certain forced-feed systems. The compounded or ADDITIVE TYPE OILS are petroleum oils to which have been added various amounts of such products as rapeseed oil, mustard seed oil, peanut oil, fish oil, tallow, or lard. These additives improve the ability of the oil to lubricate in the presence of water and steam, prevent rusting and sludging of machinery parts, and in some cases give the oil a certain detergency or cleansing character.

Lube Oil Characteristics

Lubricants obtained by the Navy are tested for such quality characteristics as viscosity, pour point, flash point, fire point, auto-ignition point, neutralization number, demulsibility, and precipitation number. On the basis of these qualities, the lubricant must:

1. Have a suitable viscosity at the temperature at which the bearing operates.
2. Form durable boundary films on the metal rubbing surfaces.
3. Not attack chemically the journal or bearing metals.
4. Not change its own chemical composition with use.

The quality points are briefly explained in the following paragraphs.

The VISCOSITY of an oil is its tendency to resist flow or change of shape. A liquid of high viscosity flows very slowly. In variable climates automobile owners, for example, change oils in accordance with prevailing seasons because heavy oil becomes too sluggish in cold weather, and light oil becomes too fluid in hot weather. The higher the temperature of an oil, the lower its viscosity becomes; lowering the temperature increases the viscosity. The high viscosity or stiffness of the lube oil on a cold morning makes an engine difficult to start.

In general, high speeds and heavy loads require low viscosity. If an oil of a higher viscosity is used under such conditions, the increased internal friction will raise the

temperature and reduce the viscosity of the oil. The viscosity must always be high enough to keep a good oil film between the moving parts—otherwise, there will be increased friction, power loss, and rapid wear on the parts. Oils are graded by their viscosities at a certain temperature—by noting the number of seconds required for a given quantity (60 millilitres) of the oil at the given temperature to flow through a standard orifice. The right grade of oil, therefore, means oil of the proper viscosity.

The VISCOSITY INDEX of an oil is based on the slope of the temperature-viscosity curve—or on the various viscosities of a given oil at various temperatures, with other conditions remaining unchanged. A low index figure denotes a steep slope of the curve, or a great variation of viscosity with temperature; a higher index figure denotes a flatter slope, or lesser variation of viscosity with identical changes in temperature. If you are using an oil with a high viscosity index, its viscosity or body will change very little when the temperature of the engine increases—the oil will not thin out.

The POUR POINT of an oil is the lowest temperature at which the oil will barely flow from a container. This property is closely related to viscosity. Generally speaking, an oil of high viscosity will have a higher pour point than one with a low viscosity. Since cold lube oil has a high viscosity, it will be difficult to pump such oil through a lubrication system. This will cause inadequate lubrication with consequent internal friction, localized high temperatures, as well as difficulty in turning over machinery.

The FLASH POINT of an oil is the temperature at which enough vapor is given off to flash when a flame or spark is present. The minimum flash points allowed for Navy lube oils are all above 315° F, and the temperatures of the oils are always far below that, unless something goes wrong. If something has gone wrong, you most certainly will have shut down before the temperature becomes dangerous.

The FIRE POINT (akin to the flash point) of an oil is the temperature at which the oil will continue to burn when ignited.

The AUTO-IGNITION POINT of an oil is the temperature at which the inflammable vapors given off from the oil will burn without the application of a spark or flame. For most lubricating oils, this temperature is approximately 750° F.

The NEUTRALIZATION NUMBER of an oil is the measure of the acid content, and is defined as the number of milligrams of potassium hydroxide (KOH) required to neutralize one gram of the oil. All petroleum products deteriorate or oxidize in the presence of air and heat; the products of this oxidation include organic acids. The acidity, if present in sufficient concentration, has harmful effects on alloy bearings at high temperatures, galvanized surfaces, and the demulsibility of the oil with respect to fresh and sea water. This last effect, in turbine installations, may result in the formation of sludge and emulsions too stable to be broken by the means available. An increase in acidity with use of the oil is an indication of deterioration.

The DEMULSIBILITY (or emulsion characteristic) of an oil is its ability to separate cleanly from any water present—an important factor in forced-feed systems. It is especially important to keep water (fresh or salt) out of oils.

The PRECIPITATION NUMBER of an oil is a measure of the amount of solids, classified as asphalts or carbon residue, contained in the oil. The number is reached by diluting a known amount of oil with naphtha and separating the precipitate by centrifuging—the volume of separated solids equals the precipitation number. The test is a quick means of determining the presence of foreign materials in used oils. An oil with a high precipitation number or carbon residue may cause trouble in an engine by leaving deposits or by plugging up valves and pumps.

Lube Oil Classifications

NAVAL TESTS AND REQUIREMENTS with regard to lube oils are rigid. The lubricant qualities and characteristics explained in the preceding section are all taken into consideration by the Bureau of Ships before oils are purchased. The Naval Engineering Experiment Station also conducts endurance tests with oils. Oils imperfectly refined break down during these tests and show chemical and physical properties differing greatly from those of the new oil. Standard specifications are set up for each class and type of oil.

The Navy classifies lubricating oils by a system of numbers called symbols. Each IDENTIFICATION SYMBOL NUMBER consists of four digits. The first digit classifies the oil according to its use, and places it into one of nine classes. The remaining three digits indicate the viscosity of the oil. The viscosity figures are actually the number of seconds required for 60 cubic centimeters of the oil at the specified temperature (either 130° or 210° F depending upon the degree of heat to which the oil will be subjected in use) to flow through a standard orifice, such as the Saybolt viscosimeter. The symbol 3080, for example, indicates that the oil is in the third class and takes 80 seconds to flow (at 210° F) through the orifice. Some of the classes comprise oils of different viscosities.

There are nine classes, or series, of Navy lubricating oils. These classes are of two general types: the MINERAL TYPE, and the COMPOUNDED, or ADDITIVE TYPE. The mineral type oils are petroleum oils derived from crude oil. The compounded, or additive oils are also petroleum oils, but with special ingredients added. According to classification within the two general types, the nine classes are discussed in the paragraphs which follow.

Mineral Oils

1000 Series. The aviation engine oils include symbols 1065, 1080, 1100, 1120, and 1150. Symbols 1100, 1120, and

1150 are of primary concern to an Engineman. Symbols 1100 and 1120 are used in the Packard engines of PT's, and symbol 1150 is used in the compressors of vapor compression type distilling plants.

2000 Series. The forced-feed oils (viscosity measured at 130° F) consist of symbols 2075 to 2250, inclusive; symbol 2075H hydraulic oil; and symbol 2190T, turbine oil. Although symbol 2190T contains additives, its use places the oil in class 2. The additive materials increase the ability of the oil to displace water from steel, and prevent oxidation, but have little effect on the demulsibility of the oil. Manufacturers of ball bearings generally specify that bearings for the turbine-driven auxiliaries must be lubricated with 2190T oil.

3000 Series. The forced-feed oils (viscosity measured at 210° F) consist of symbols 3042 to 3150, inclusive. Navy oil symbol 3080 is used in the oil systems of all turbine-driven pumps incorporating worm gears.

5000 Series. The mineral marine-engine and cylinder oils include symbols 5150, 5190, and 5230. Oils in this class were developed for machinery with steam cylinders, where an oil must not only withstand high temperatures but must also have good demulsibility properties.

Compounded or Additive Oils

Compounded marine reciprocating engine and cylinder oils contain varying amounts of additives which improve the ability of the oils to lubricate in the presence of water and steam. Because of their emulsibility, oil symbols 4065, 6135, 7105, and 8190 should never be used in a forced-feed lubricating system.

4000 Series. Symbol 4065 is a compounded marine reciprocating engine oil (viscosity measured at 210° F). This oil emulsifies quickly when mixed with water, and forms a lather which will not wash off metal surfaces as readily as a straight oil.

9000 Series. These heavy-duty lubricating oils are represented by the symbols 9110, 9170, 9250, and 9370 (vis-

cosity measured at 130° F), and by symbol 9500 (viscosity measured at 210° F). These oils should be used in accordance with the viscosity specified for the particular equipment.

Frequently Used Oils

As an MM3 working in the machinery spaces aboard ship, there are four grades of oil, mineral and compounded, which you will be using more frequently than any of those discussed previously. Oil, symbol 2190T, is used as a lubricant for the main engines and many turbine-driven auxiliaries. Turbine-driven pumps which incorporate worm gears are lubricated with oil symbol 3080. Most refrigerating equipment lubrication systems use oil symbol 2135; and the lubricant for hydraulic equipment is oil symbol 2075H.

LUBRICATING GREASES

As with the lubricating oils, you should know what types of lubricating greases exist, of what these greases are composed, how and why they are classified by the Navy, and exactly where each grease is to be used.

Types of Greases

Lubricating greases are gels of soap and lubricating oil. Fillers, such as graphite, are also added to some greases to make the greases more effective for certain lubrication requirements.

The soap used in the common SOAP AND OIL GREASES are chemical compounds formed by reacting fats or fatty acids with various alkaline materials such as lime, soda, aluminum, zinc, barium, lithium, lead, and potassium. The common SODA SOAP GREASES are used for applications where no water is present and where operating temperatures approach 200° F. The common LIME SOAP GREASES do not absorb moisture or emulsify as readily as the soda soap greases, but have lower melting points. They are used as general purpose greases for light load applications at

ordinary operating temperatures. These two types of greases will satisfactorily lubricate the majority of machinery.

Certain additives are given to the ordinary lubricating greases to provide for specific conditions. These SPECIAL ADDITIVE GREASES are identified by the additive. LEAD OLEATE SOAP GREASES, for example, are used for certain bearing surfaces which are so heavily loaded that the ordinary grease will not maintain a film to prevent contact of the rubbing surfaces. EXTREME PRESSURE GREASES also incorporate special additive agents to provide necessary film strength.

OXIDATION INHIBITOR GREASES have an additive incorporated to assure better stability at high temperatures and to prevent rusting under these conditions. In GRAPHITE GREASES, the added graphite acts as a mild abrasive to help smooth roughened surfaces, acts as a filler to smooth over unequal surface spots, and substitutes its own low friction for that of the metal it covers. The last characteristic mentioned is especially important where a bearing is exposed to temperatures so high that ordinary grease or oil would break down. Except for such high temperatures, graphite grease should not be used in bearings which are in first-class condition.

Each of these several types of greases is supplied in three grades: soft, medium, and hard. The SOFT GRADES are used at high speeds under light pressure; the MEDIUM GRADES are used at medium speeds under medium pressure; and the HARD GRADES are used at slow speeds under heavy pressure.

Grease Classification (Navy Specifications)

Navy specifications have been developed to cover the following grades of lubricating greases:

1. Mineral soap lubricating grease (specification 14G1).
   Grade I.................................Soft.
   Grade II.............................Medium.
   Grade III...............................Hard.

2. Graphite lubricating grease (specification 14G2).
   Grade A............Soft (2 to 3 percent graphite).
   Grade B.........Medium (2 to 3 percent graphite).
   Grade C...........Hard (2 to 3 percent graphite).
   Grade AA..........Soft (4 to 5 percent graphite).
   Grade AB.......Medium (4 to 5 percent graphite).
3. Ball and roller bearing lubricants (specification 14L3).
4. Universal and gear lubricants (specification 14L4).
5. Nonslick waterproof lubricants (specification 14L5).
   Type A..............................Nonfloating.
   Type B..................................Floating.
6. Plug-type scupper valve lubricant (specification 14L6).
7. High-temperature water-resistant lubricant (specification 14L7).
8. Turret roller and pinion lubricant (specification 14L8).
9. General purpose lubricant No. 1 (specification 14L9).
10. General purpose lubricant No. 2 (specification 14L10).
11. Water pump lubricant No. 4 (specification 14L11).

STANDARD NAVY LUBRICATION

Always be sure that you are using the particular lubricant which is specified for the individual machinery part, unit, or system you are concerned with on your watch.

Most ships make up LUBRICATING CHARTS for quick reference on this information. These charts generally contain a line diagram of the unit or system, point of lubrication, symbol of lubricant, quantity, and interval of supply—along with applicable general instructions, operating hints and possible casualties. The charts are usually kept posted in machinery compartments. Both oils and greases are indicated.

The MANUFACTURER'S INSTRUCTION BOOK for each unit of machinery is the basic reference for correct lube oil, if no lubrication chart (which is based on the manufacturer's instructions) is available.

Other references with regard to correct lubrication consist of the TABLE OF RECOMMENDED OILS, which is printed in chapter 45 of the *Bureau of Ships Manual;* and the BuShips, Lubricating Oil General Information, Requirements, and Methods of Test (N. B. S. 431), containing data concerning the characteristics and uses of Navy oils. These sources may be referred to in the log room.

SPECIFIC CONSIDERATIONS are given to the lubrication of various engineering machinery units. These discussions are given in the preceding chapters devoted to this machinery, and in detail in the manufacturers' instruction books.

Now that we have given some attention to the various types and characteristics of Navy lubricants, we should consider the several methods or systems in which the lubricants are used—the forced-feed systems, gravity-feed systems, self-oiling bearings, grease lubrication systems, and ball and roller bearing lubrication.

FORCED-FEED LUBRICATION SYSTEMS

The forced-feed lubricating oil systems are employed for the lubrication of main turbines and reduction gears, turbogenerators, feed pumps and other auxiliary machinery, and in some internal-combustion engines. Each engineroom lube oil system is arranged for independent operation, and generally there is no service connection provided between enginerooms. The main engine lubricating systems include a purifier; whereas the other smaller systems must be periodically drained (as the crankcase of an automobile is drained) and replaced with new or purified oil.

The essential parts of the forced-feed system (fig. 6–2) include pumps, drain tanks, coolers, settling tanks, strain-

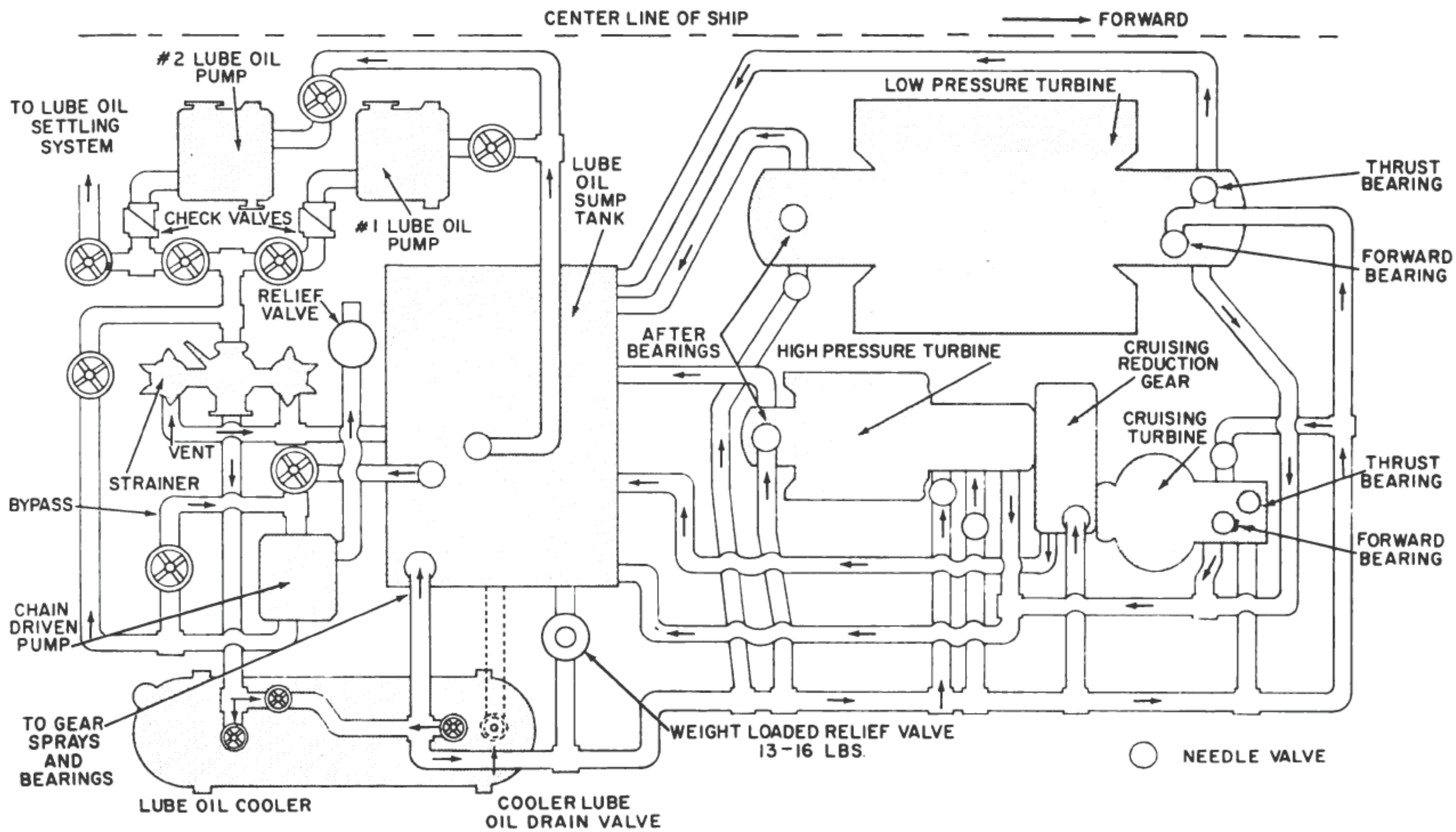


Figure 6-2.—Diagram of a typical modern turbine forced-feed lubricating oil system.

ers, filters, purifiers, heaters, piping, and miscellaneous fitting (valves, gages, thermometers, etc.).

Oil Service System

Figure 6–2 illustrates a lubrication system for one main engine installation. The DRAIN TANK or sump tank is located under the reduction gears in the reduction gear case. Two OIL PUMPS (fig. 6–3) are provided, but only one is used at a time. On some ships, the latest practice is to have the primary supply from a pump which is geared directly to the main shaft. The second pump is always warmed up and ready for instant use in the event that the operating pump fails. The standby pump if properly

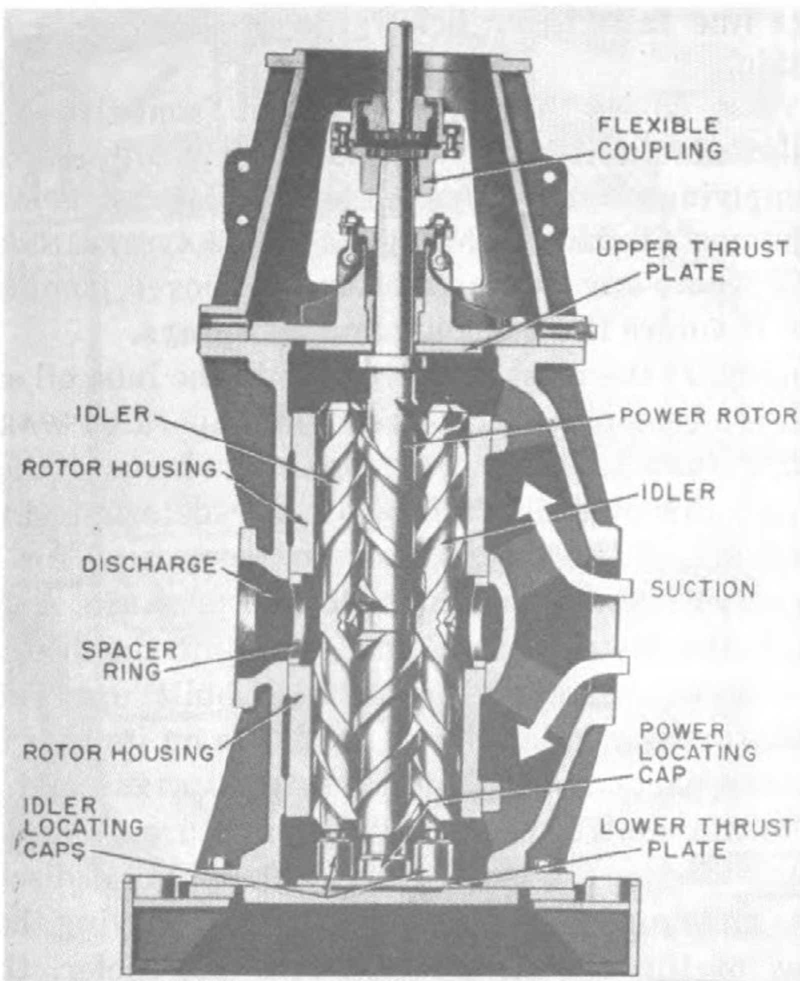


Figure 6–3.—Typical main lube oil service pump.

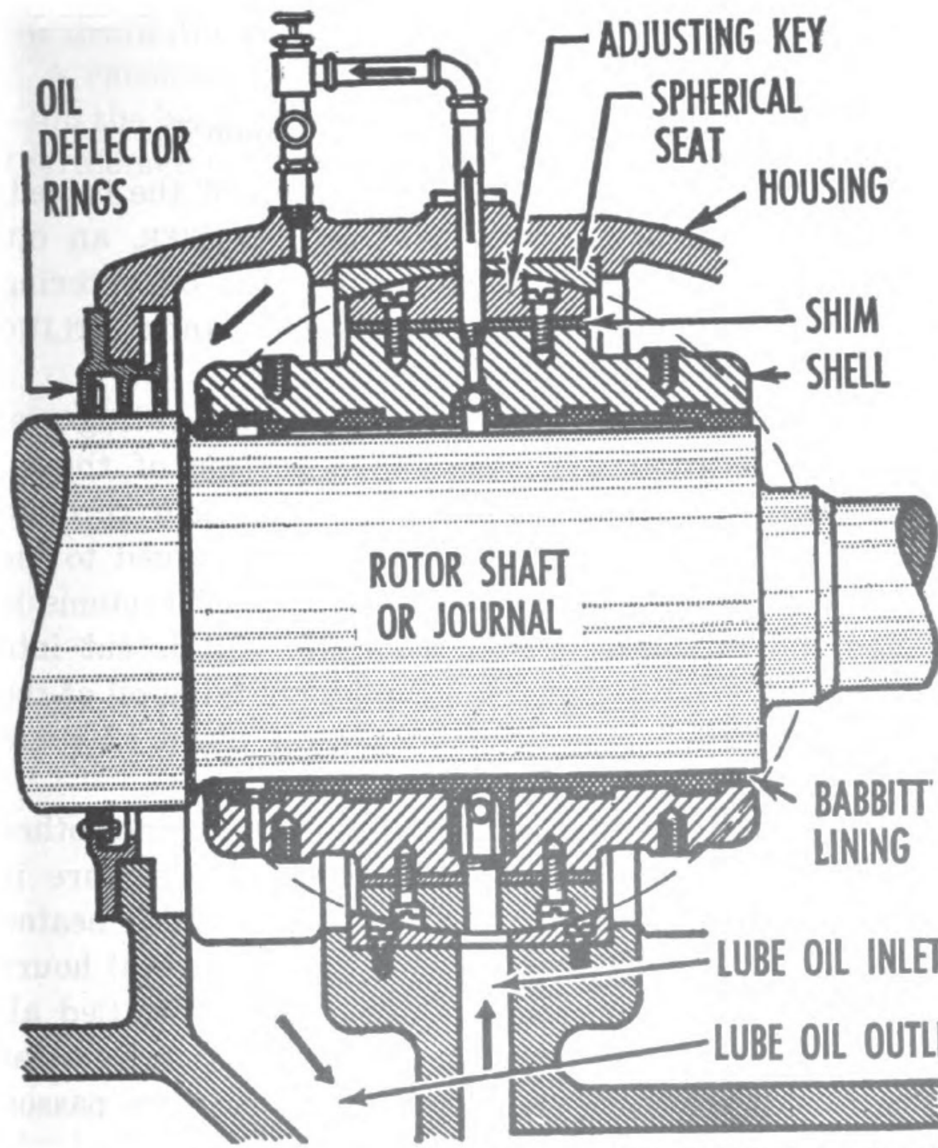
lined up, will generally start automatically in emergencies.

Lube oil pumps are generally provided with an automatic cut in device which start the pump, if properly lined up for standby service, when the lubricating supply line pressure falls below a certain value. Motor-driven pumps have a pressure actuated switch; turbine-driven pumps have Leslie pump governors (pressure regulators). For example, the governor on the pump in use might be set to maintain a discharge pressure of say 25 psi, and the governor of the standby pump for some pressure less than 25 psi. If the pump in use fails for some reason, the governor of the standby pump will automatically start the standby pump when the pressure in the lube supply discharge line falls to or below the pressure it is set to maintain.

In cases where the pump is driven from the shaft of the lubricated unit it serves, a PRIMING PUMP is provided for supplying oil to the system before the unit is started. The pumps discharge through a DUPLEX STRAINER AND FILTER, where any foreign matter is removed from the oil before it enters the bearings and oil sprays.

Usually, at the most remote point in the lube oil supply line to the bearings a pressure switch operated WARNING SIGNAL is installed. It is set to operate whenever the lube oil supply line pressure falls below a predetermined value, thereby giving the throttleman (or operators, for other machinery) instant warning of low oil pressure. A RELIEF VALVE is also installed to discharge oil into the drain tank whenever excessive oil pressure is built up. The OIL COOLER, through which the oil may pass on its way to the lubricated parts, is fitted with THERMOMETERS and a BY-PASS to aid control of the oil temperature. VALVES are also provided in the cooling water supply and discharge lines to and from the cooler to provide for varying the rate of flow of the cooling water. From the cooler, the oil passes to individual bearings through NEEDLE VALVES.

These valves regulate the oil flow to the individual bearings. From the bearings, the oil is drained back to the drain tank. Oil is supplied to the teeth of the reduction gears through SPRAY NOZZLES, after which the oil drains to the drain tank below. A FLOAT GAGE on the drain tank indicates the oil level. As additional oil is required for the system, it is drained or pumped into the drain tank from



Courtesy of U. S. Naval Institute

Figure 6-4.—Typical adjustable spherical seated bearing lubricated by forced feed.

the STORAGE TANK. The oil may be run through an OIL HEATER to raise the temperature of the oil in the system, particularly prior to warming-up the main propulsion machinery.

Figure 6–4 illustrates a typical main turbine bearing which is lubricated by a forced-feed lube oil service system. Since these bearings are located close to the shaft glands, OIL DEFLECTORS are fitted to prevent leaking gland steam from contaminating the lube oil, and to prevent the oil from escaping.

Oil Purifying and Settling System

The oil purifying and settling functions of the forced-feed system include a centrifugal OIL PURIFIER, an OIL HEATER for raising the temperature of the oil entering the purifier (to facilitate removal of water), and SETTLING TANKS fitted with steam heating coils.

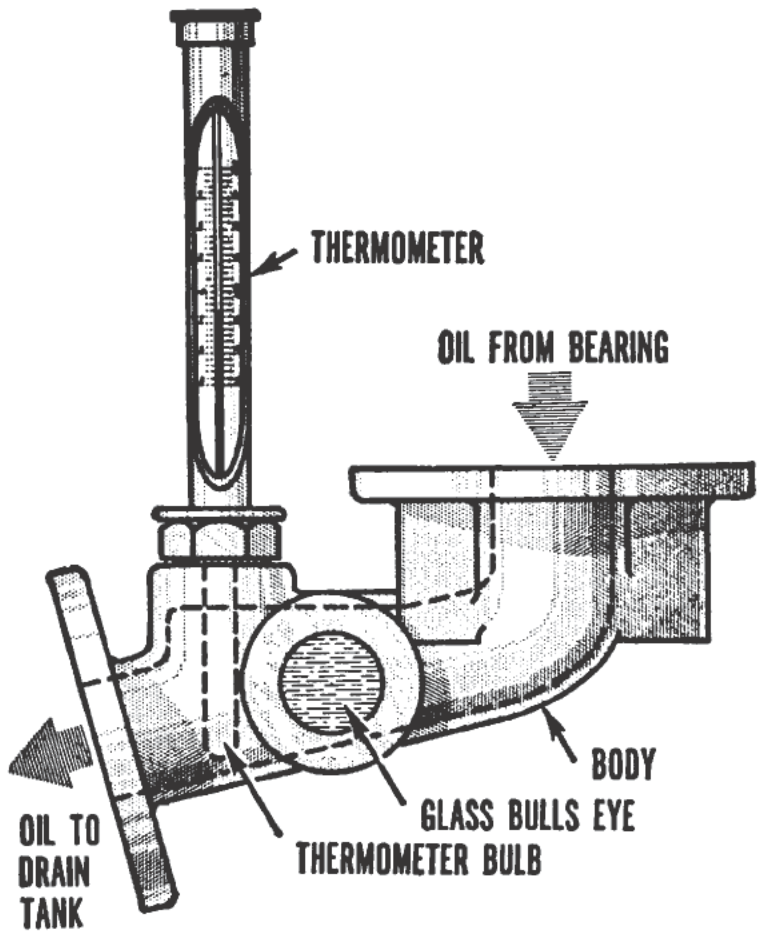
The oil is normally purified, while the lubricating system is in operation, by bypassing a portion of the oil discharged to the service system and passing it through the PURIFIER. From the purifier, oil is discharged to the drain tank. Oil from the smaller forced-feed systems is drained and put into a tank, from which it is cut into the purifier when it is not employed in purifying oil of the main system. The purifier is generally run about 12 hours a day for the main system.

If the oil becomes badly contaminated by water or other impurities, or if it becomes emulsified, the mixture is pumped up to the SETTLING TANKS. Here the oil is heated to 180° F by the steam-heated coils. After several hours at this temperature, the impurities will have settled almost entirely and can be drawn off through the drains at the bottom of the tanks. The remaining oil is then passed through the purifier and discharged to the drain tank. Purification by heating and settling can be done only in port, because all the oil must be pumped out of the sump.

Oil Check Fittings

Various means are provided for maintaining a continuous check on the supply of oil to bearings and on the temperature of oil flowing from the bearings. In modern turbines and reduction gears, a THERMOMETER is installed in the line leading from the bearing, and a bull's-eye SIGHT-FLOW fitting is mounted in the supply line leading to the individual bearing. A combined sight-flow and thermometer fitting (fig. 6–5) is sometimes installed in the drain line from each bearing.

A PRESSURE GAGE is also installed outside the gear case —on the header from which oil is fed to the bearings. The thermometers are sometimes of the distant-reading type



Courtesy of U. S. Naval Institute

Figure 6–5.—Combined lube-oil sight-flow and thermometer fitting.

—with the recording bulbs connected to a dial-type indicator.

Oil Pressures

The pressures to be carried at the various parts of the lubrication system differ with the type of installation. Pressure at the service pumps should be such that the pressure at the bearing (with the lowest reading) will be according to the manufacturer's specification. A higher pressure than this will cause the bearings to become flooded and the oil to foam. Pressures shown by the oil gages on the main gage board should indicate the actual pressure at the low-pressure alarm connections to the system. Sudden increases in pressure at the pump (usually due to a clogged strainer or pipeline) should prompt immediate checking of oil flow at the bearings. The trouble should be located and corrected at once.

The flow of oil at the bearing, as seen through the sight-flow glass, must be uniform. Frequent inspections should be made during each watch. If the oil supply is interrupted at any time, the main shaft should be stopped immediately and the bridge notified. Be sure to keep sight glasses clean.

Oil Temperatures

Bearing temperatures depend on the viscosity of the oil being used, design of the bearing, rpm, and clearances. The manufacturer's instruction book for a unit gives the correct temperatures of lube oil flowing from the bearings. The temperature rise of oil passing through the bearings should not exceed 50° F, even though the maximum allowable temperature is not exceeded. Investigate the cause of any rising temperature that fails to level off, no matter how slowly it is rising.

Since friction loss in a journal bearing is directly proportional to the oil viscosity, and the viscosity depends upon the temperature, the oil leaving the cooler should be between 120° and 130° F. The efficiency of double reduc-

tion gears, for example, will be decreased appreciably at cruising speeds if operated at temperatures lower than those prescribed.

Take PRECAUTIONS WITH THE THERMOMETERS. Make certain that the bulbs are sufficiently inmmersed in the oil streams to give an accurate reading. In many cases, too, the thermometers give only the average temperature in the bearing reservoir. Checks on temperature should, therefore, be periodically made by feeling the cap and by inspecting the sight glasses to ensure that there is a flow of oil.

The OIL COOLERS should be put into operation when the temperature of the oil from the cooler reaches 120° F. The temperature from the cooler should be carried at 120° to 130° F. When the system has more than one cooler, the coolers should be used alternately. The operating principles of the lube oil cooler will be discussed in the next chapter.

Oil Purity

The purity of the lube oil is very important for efficient lubrication, and careful attention should be given to keeping the oil free of both metallic particles and water.

The oil strainers should be removed and cleaned during each watch. All residue found in the strainers should be carefully examined. If pieces of metal are found, determine the character of the metal. Later ships have strainer magnets installed to remove ferrous (iron) particles from the oil. Bits of brass or babbitt metal indicate that there is a damaged, or wiped, bearing in the system, or that the bearing metal is breaking up. If the metal has the appearance of rust, it indicates that corrosion is occurring in the system. Pieces of metal rust will scratch the bearing or mar a thrust shoe. A sudden rise in bearing temperature, followed by a return to normal, usually indicates that some foreign substance reached the bearing, scratched it, and was then washed out by the oil supply.

Every effort should be made to prevent the entry or to

effect the IMMEDIATE REMOVAL OF WATER IN THE OIL. Water not only increases the frictional resistance, and causes the oil film to break down prematurely, but also corrodes the bearing journals. Water may actually cause corrosion in the entire system, particularly in those parts which are not covered with oil at all times. Condensation of moisture, which promotes rusting on exposed surfaces such as gear casings, upper portions of drain tanks, etc., should be prevented by eliminating factors which tend to reduce the temperature of the surfaces. All unprotected escape hatches in the vicinity of gear casings must be kept secured at all times when the temperature of the outside air is less than 70° F, except when engines are secured. Air from ventilation ducts should never blow directly or indirectly on the gear casing. When coming to anchor, or securing main propulsion machinery, circulate oil through the system for at least an hour to minimize the effects of an unavoidable amount of fresh-water condensation.

Water enters the lubrication system at the following principal points:

1. Leaky tubes or joints in the oil coolers.
2. Steam-sealed glands of turbines (sometimes because of a choked drain).
3. Vents on tanks and gear casings (as atmospheric moisture, subsequently condensed).
4. Leaks in drain or sump tanks located in bilges.
5. Leakage of products of combustion (containing water vapor) past the piston rings and into diesel engine crankcases.

Lube oil may lose its lubricating qualities if it is contaminated, but if the impurities and water are removed as soon as their presence is noted, the oil can be used over and over indefinitely. To ensure that the oil is kept free of all foreign matter, a sample of lube oil should be drawn from the auxiliary machinery sumps about once a week. Allow this sample to settle and examine for contamination. If the lube oil shows any contamination, drain

the oil system of the particular piece of auxiliary machinery, and replenish the system with clean lube oil. The contaminated oil should be placed into one of the settling tanks and purified at some later date.

CENTRIFUGAL PURIFIERS (centrifuges) are used to purify the lube oils. Because of the importance of this purifier, and because it is employed for the purification of lube oil used in other than forced-feed systems, it is treated somewhat fully further on in this chapter. Generally, the oil must be heated to higher than operating temperature before being run through the centrifuge. This results in a greater degree of purification. Most oils may be heated to 180° F without injury, but prolonged heating at higher temperatures will cause the oils to oxidize.

GRAVITY-FEED LUBRICATION SYSTEMS

There are two types of gravity-feed lubricating systems—the gravity force feed and the straight gravity feed. The straight gravity-feed system is further differentiated as being either a DRIP-FEED or a WICK-FEED system. None of these systems will be found to any great extent on modern naval ships. They are described in chapter 45 of the *Bureau of Ships Manual.*

SELF-OILING SPRING BEARINGS

Spring bearings on the main propulsion shaft (fig. 6–6) are lubricated by a self-oiling system. Most of these bearings are ring-oiled, though some are chain-oiled. You must know how to ensure continuous correct lubrication of these important units.

Ring-Oiled Spring Bearings

As shown in figure 5–13, the lubrication system for the ring-oiled bearings consists of an OIL SUMP below the bearing journal, and brass OILER RINGS (or chain loops) which are hung loosely over the journal and lower half

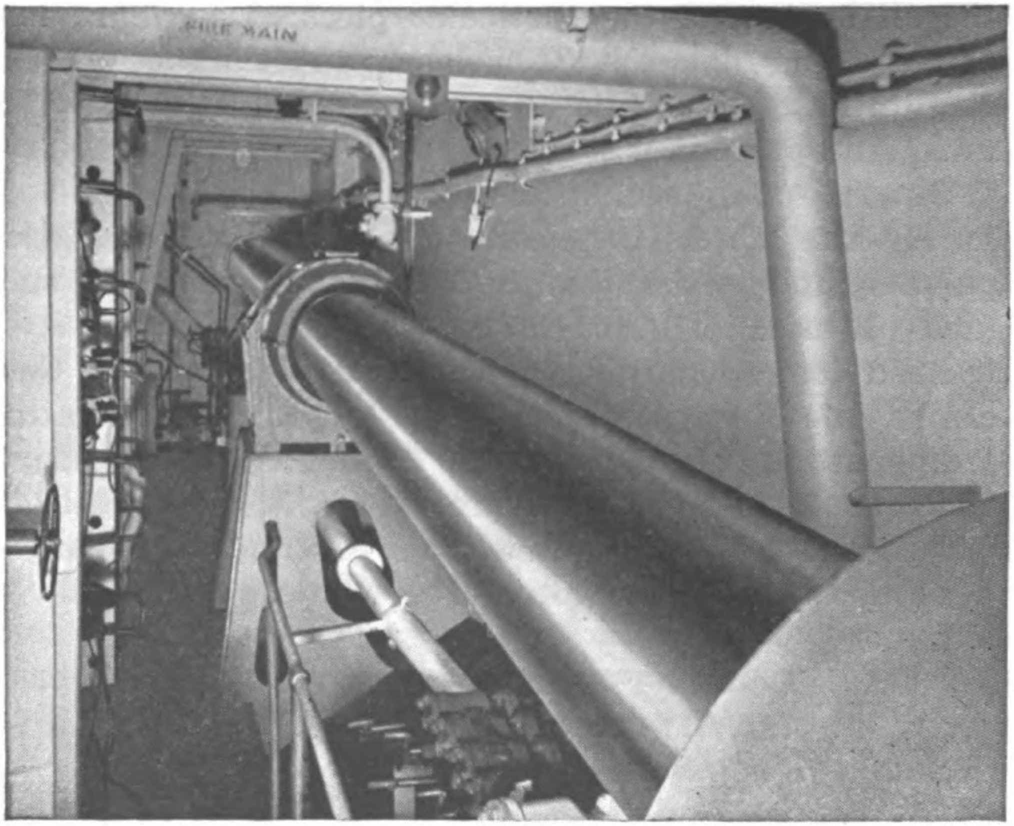


Figure 6–6.—A main propulsion shaft and self-oiling spring bearing in the shaft alley of a modern ship.

of the bearing. These rings are immersed in the oil and carry a continuous supply of oil over the journal as the rings are dragged around by the rotation of the shaft. The rings must be finished smoothly to prevent hanging and failure to rotate evenly. The upper half of the bearing is cut away in the middle to accommodate the oiler rings. A hinged ACCESS COVER in the upper half of the bearing housing permits inspection of the journal and oiler rings. The OIL DEFLECTOR RINGS, secured to the shaft, keep the oil within the bearing space.

Chain-Oiled Spring Bearings

Roller chains, such as are commonly used in chain-and-sprocket mechanisms, are sometimes installed in place of the oiler rings. These CHAIN OILERS have the advantage of being more easily removed and replaced, but they are

also more subject to wear and breakage. They require more frequent inspection than oiler rings. When renewals are made, care must be taken to see that the new chain is not so long that it drags on the bottom of the oil well. This would not only cause the chain to wear rapidly but would also cause it to wear a hole through the bottom of the oil sump.

Care of Spring Bearing Oil

The oil level in the sumps should neither fall below that which is indicated for the minimum, nor be allowed to rise above the maximum mark. The frequency of changing the oil and cleaning the oil sumps depends upon the service and the mechanism. If the oil doesn't become contaminated by impurities, it can be used for an extended period before the lubricating qualities are reduced. Regardless of condition, the oil should be drained once a quarter and run through the purifier. Whenever the oil is renewed, the sump should be thoroughly cleaned. Be sure to keep inspection openings in operating condition, and closed when not in use.

Samples of the oil in the sump should be examined after each extended run, and after 10 days of intermittent service. If the oil shows an increase in viscosity, discoloration, or formation of sludge deposits in the reservoir, immediate renewal is necessary. When under way, the oil level and bearing operations must be inspected and logged hourly.

GREASE LUBRICATION SYSTEMS

Grease lubrication is employed in many locations where the retention of lube oil at the bearing surface would otherwise be difficult. The grease is applied either through the use of grease cups or through pressure fittings.

Grease Cup Lubrication

Dirt in lube oil will generally settle, but dirt mixed in lubricating grease is abrasive. For this reason, particu-

lar care must be taken to prevent contamination, especially where grease cups are used. Before opening the container, all dirt should be carefully removed from the exterior. No dirt must be allowed to enter either the opening or the grease cups. The cups should be frequently emptied, cleaned, and refilled with fresh grease.

Pressure Greasing

Pressure fittings, such as the zerk type, form a convenient means of lubricating numerous low-speed, lightly loaded, or widely separated bearings. They are not, however, satisfactory for use on electric generators and motors because of the danger of forcing grease out of the bearing and onto windings. These fittings are similar to those on an automobile, where grease guns are employed for lubrication.

Before applying the grease gun, the pressure fittings should be wiped clean. The gun tip, too, must be clean. The pressure should be applied until grease comes out around the edges of the bearing. In bearings fitted with felt or other seals, care must be taken to avoid breaking the seals by overpressure. Excessive pressure in the lubrication of needle-type roller bearings may unseat the needles.

BALL AND ROLLER BEARING LUBRICATION

The oil or grease employed for the lubrication of ball and roller bearings (known jointly as ROLLER BEARINGS) provides a lubricating film between the balls and rollers and the retainers, and between ends of the rollers and the races; dissipates heat caused by deformation of load-carrying members; prevents corrosion of the highly polished parts; and aids in excluding dirt, water, and other foreign matter. The lubricant specified for each machine should be used, and excessive lubrication should be avoided. About once a year the bearings must be oil-flushed.

Oil Lubrication of Roller Bearings

Where ball or roller bearings are oil lubricated, the lube oil, as speeds increase, begins churning and produces heat. The quantity of oil must, therefore, be reduced accordingly, until at very high speeds only a mist of oil is desirable. It is common practice to fill the bearing housing to a point between the center of the lower ball and the lowest point of the inner ring, depending upon the speed of operation. DRAINS are generally installed to prevent the oil from rising above this point; SIGHT INDICATORS are also provided. For extremely high speeds, the drip-feed or wick-feed gravity lubrication is sometimes used.

Grease Lubrication of Roller Bearings

To supply grease to ball or roller bearings, remove the relief plug at the bottom of the bearing closure and free a hole through the cavity. With the mechanism running, slowly turn down the grease cup plug at the top until grease begins to push through the relief plug hole. Leave the hole open for 10 to 15 minutes, then free the hole again with a clean rod or knife and replace the plug. Enough grease should be added to the bearing closure to make it $\frac{1}{3}$ to $\frac{1}{2}$ full.

CENTRIFUGAL LUBE OIL PURIFIERS

In the forced-feed lubrication systems on modern naval vessels, if the purity of the oil remains intact, the oil may be kept in service for a long period of time. LUBE OIL DOES NOT WEAR OUT; it is merely robbed of its lubricating properties by foreign substances. In other words, improper performance of a correct oil is not due to internal change, but to contamination or to the formation of sludge. No one would ever willfully pour into the lubrication system of his machine a mixture of oil, water, sand, fine metallic particles, sludge, and acid. Yet lubricating systems do contain mixtures of this nature, when preventive measures are not taken. The centrifugal oil purifier is

employed on all naval vessels to remove the water and other foreign matter from the lube oil. Water is the greatest source of contamination.

Contamination must be removed or the oil will not meet lubrication requirements. Dirt, sludge, and other contaminants will act as abrasives to score and scratch the rubbing metal surfaces within engines, generators, pumps, blowers, etc. Contaminants interfere with the ability of the oil to maintain a good lubricating film between metal surfaces.

Several different devices are used to keep the oil as clean as possible. Each device is designed to remove certain kinds of contamination and it takes several types of devices in a lubricating system to keep oil in a usable condition. Strainers, filters, settling tanks, and centrifugal purifiers are the devices used to free oil of contamination. Strainers and filters will not be discussed in this chapter—settling tanks and purifiers will be discussed, with emphasis on purifiers.

Settling Tanks

Shipboard lubricating systems include settling tanks (used-oil tanks) which permit used oil to stand while accumulated water and other impurities settle out. Settling is due to the force of gravity. A number of layers of contamination may form, the number depending upon the difference in specific gravity of the various substances which contaminated the oil. Settling is accelerated if the oil is kept warm while in the settling tanks.

Even though settling tanks do much in the way of removing contamination from lube oil, most ships have additional equipment to purify the oil by removing water and impurities not removed by other devices. The machines which perform the purification process are called centrifugal purifiers.

Detailed instructions on construction, operation, and maintenance of purifiers are furnished by the manufacturers. Such instructions should be carefully studied and

followed when you are responsible for the operation and maintenance of a purifier. The following general information is provided to familiarize you with the methods of purification, and the purpose and principles of operation of purifiers.

Oil system piping aboard ship is generally arranged to permit two methods of purifying oil: batch purification and continuous purification.

In the batch process, the lube oil is transferred from the sump to a settling tank by means of a transfer pump. In the settling tank, the oil is heated and its temperature maintained between 150° and 180° F for several hours by means of steam-heated coils. Water and other impurities are drained from the settling tanks through a valve. The oil is then centrifuged and returned to the sump from which it was taken. The batch process is used only while a ship is in port.

In the continuous purification process, the centrifugal purifier takes suction from a sump tank and, after purifying the oil, discharges back to the same sump. The continuous method of purification is used while a ship is under way.

Principles of Purifier Operation

A centrifugal purifier is essentially a container which is rotated at high speeds while contaminated oil is forced through and rotates with, the container. The centrifugal force imposed on the oil by the high rotating speed of the container acts to separate the suspended foreign matter from the oil. However, only materials that are insoluble in one another can be separated by centrifugal force. For example, salt cannot be removed from sea water by centrifugal force because the salt and water are in solution. Water, however, can be separated from lube oil because water and oil, when mixed, do not form a solution. Furthermore, it is necessary that there be a difference in specific gravity between the materials to be separated.

When a mixture of oil, water and sediment stands undisturbed, gravity tends to form an upper layer of oil, an intermediate layer of water, and a lower layer of sediment. The layers form because of the difference in the specific gravity of the substances in the mixture. If the oil, water, and sediment are placed into a rapidly revolving centrifugal purifier, the effect of gravity is negligible in comparison with that of the centrifugal force. Since centrifugal force acts at a right angle to the vertical axis of rotation of the container, the sediment, because of the greater specific gravity, assumes the outermost position, forming a layer on the inner surface of the container. Water, being heavier than oil, forms an intermediate layer between the layer of sediment and the oil, which forms the innermost layer. Centrifugal purifiers are so designed that the separated water is discharged as waste and the oil is discharged for reuse. The solids remain in the rotating unit and are to be cleaned out when necessary.

Effectiveness of separation by centrifugal force is further affected by the size of the particles, by the viscosity of the fluids, and by the time during which the materials are subjected to the centrifugal force. In general, the greater the difference in specific gravity between the substances to be separated and the lower the viscosity of the oil, the greater will be the rate of separation.

Use of Purifiers

In the purification process, a purifier may be used to remove water and sediment from oil or to remove sediment only. When water is involved in the purification process, the purifier is called a SEPARATOR. When the principal item of contamination is sediment, the purifier is used as a CLARIFIER. When used to purify lubricating oil, a purifier may be used as either a separator or a clarifier. Whether a purifier is used as a separator or a clarifier depends upon the moisture content of the oil to be purified.

If an oil contains no moisture, it needs only to be

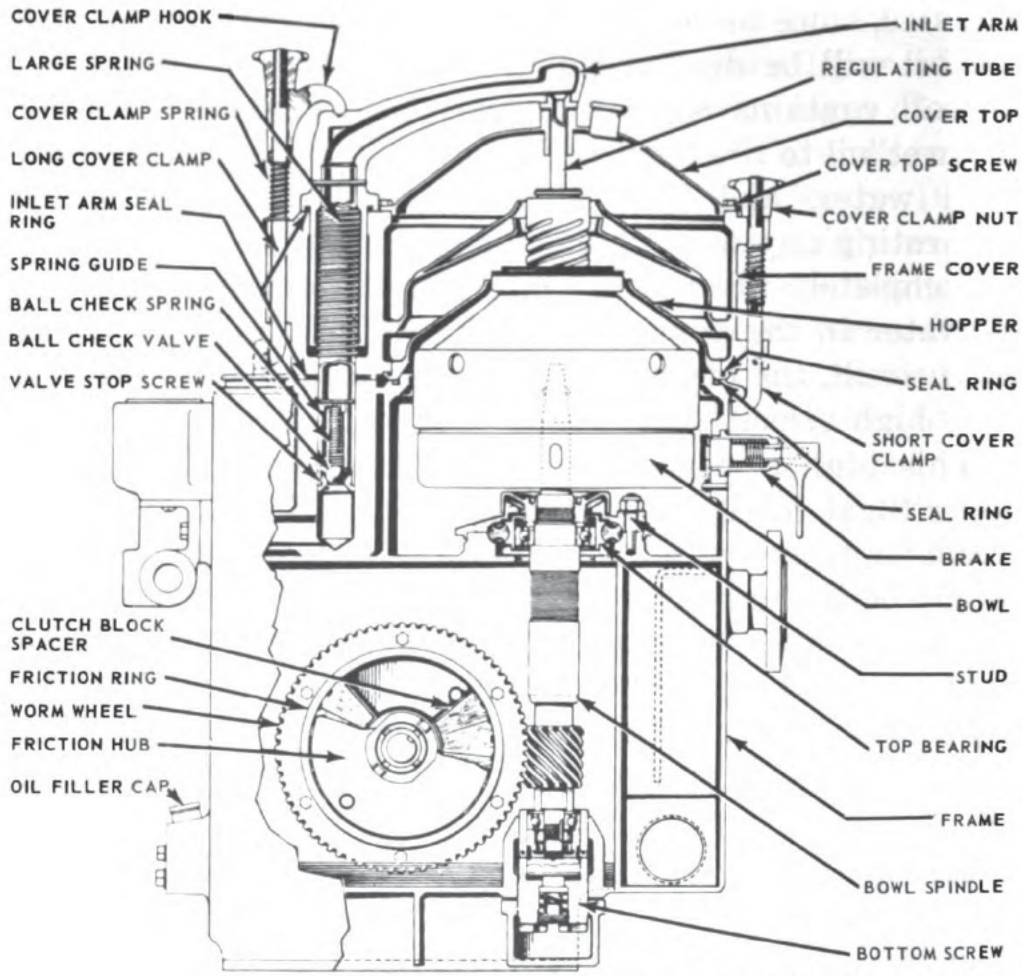
clarified, since the solids will be deposited in the bowl, and the oil will be discharged in a pure state. If, however, the oil contains some moisture, the continued feeding of "wet"oil to the bowl results eventually in a bowl filled with water, and from then on the centrifuge is not separating any water from the oil. Even before the bowl is completely filled with water, the presence of a layer of water in the bowl reduces the depth of the oil layer. As a result, the incoming oil passes through the bowl at a very high velocity.

This higher velocity means that the liquid is under centrifugal force for a shorter time, and the separation of water from the oil is, therefore, not so complete as it would be if the bowl were without the water layer, or if the water layer were a shallow one. Because of this, the centrifuge should not be operated as a clarifier unless the oil contains very little or no water. A small amount of water can be satisfactorily accumulated, together with the solids, to be drained out when the bowl is stopped for cleaning. However, if there is any appreciable amount of water in the oil, the bowl should be operated as a separator.

Types of Centrifugal Purifiers

There are two types of purifiers used in Navy installations. Both types operate on the same principle. The principal difference in the two types of purifiers is in the design of the rotating units. In one type the rotating element is a bowl-like container which encases a stack of disks and in the other type the rotating element is a hollow, tubular rotor; thus, they are known as the DISK-TYPE PURIFIER and the TUBULAR-TYPE PURIFIER.

A sectional view of a disk type centrifugal purifier is shown in figure 6–7. The bowl is mounted on the upper end of the vertical bowl spindle, which is driven by means of a worm wheel and friction clutch assembly. A radial thrust bearing is provided at the lower end of the bowl



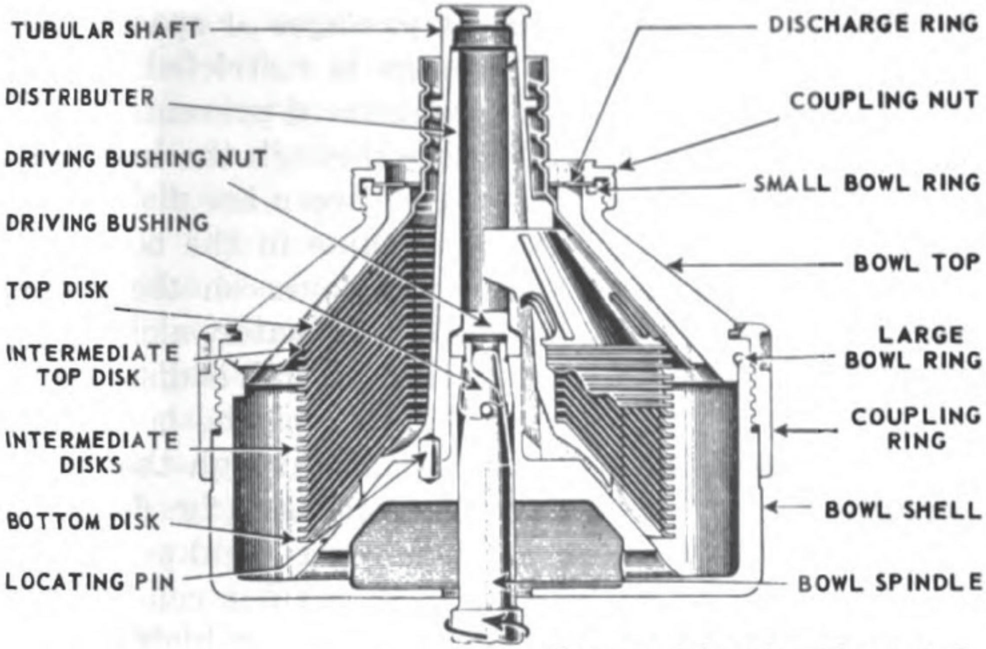
Courtesy of the DeLaval Separator Co.

Figure 6–7.—Disk-type centrifugal purifier (DeLaval).

spindle to carry the weight of the bowl spindle and to absorb any thrust created by the driving action.

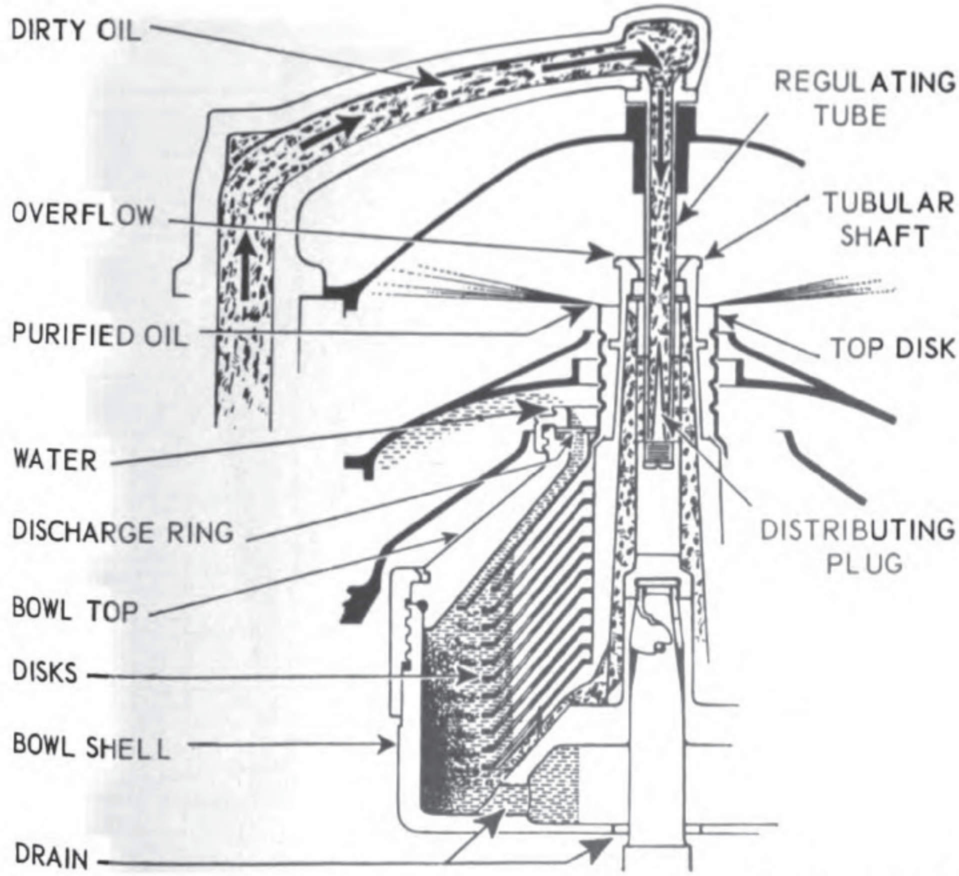
The parts of a disk-type bowl are shown in figure 6–8. The flow of oil, through the bowl and additional parts, is shown in figure 6–9.

Contaminated oil enters the top of the revolving bowl through the regulating tube. The oil then passes down the inside of the tubular shaft and out at the bottom into the stack of disks. As the dirty oil flows up through the distribution holes in the disks, the high centrifugal force exerted by the revolving bowl causes the dirt, sludge, and water to move outward and the purified oil inward toward the tubular shaft. The disks divide the space within the



Courtesy of the DeLaval Separator Co.

Figure 6-8.—Parts of a disk-type purifier bowl.



Courtesy of the DeLaval Separator Co.

Figure 6-9.—Path of contaminated oil through disk-type purifier bowl (DeLaval).

bowl into many separate narrow passages or spaces. The liquid confined within each passage is restricted to flow only along the passage. This arrangement prevents excess agitation of the liquid as it passes through the bowl and creates shallow settling distances between the disks.

Most of the dirt and sludge remains in the bowl and collects in a more or less uniform layer on the inside vertical surface of the bowl shell. Any water, along with some dirt and sludge, separated from the oil, is discharged through the discharge ring at the top of the bowl. The purified oil flows inward and upward through the disks, discharging from the neck of the top disk (fig. 6–9).

A cross section of a tubular-type centrifugal purifier is shown in figure 6–10. This type of purifier consists essentially of a rotor or bowl which rotates at high speeds. It has an opening in the bottom to allow the dirty lube oil

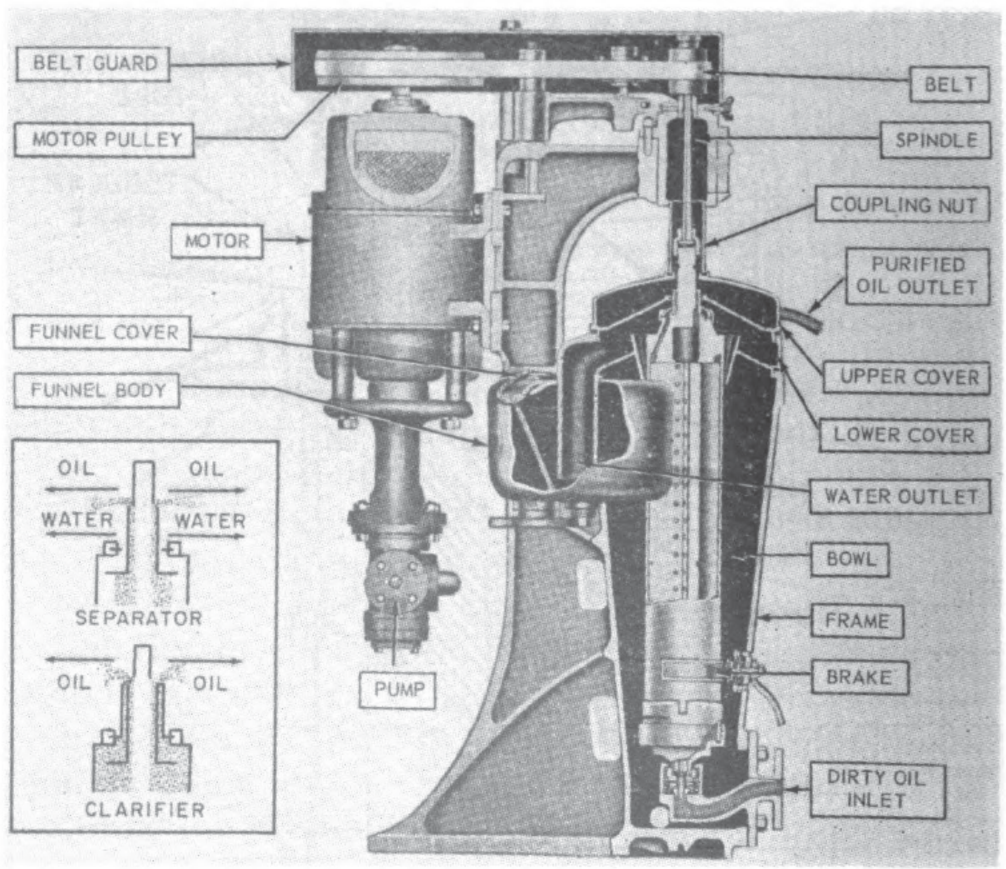


Figure 6–10.—Tubular-type centrifugal purifier (Sharples).

to enter and two sets of openings in the bowl top to allow the oil and water (separator) or the oil by itself (clarifier) to discharge (see insert fig. 6–10). The bowl, or hollow rotor, of the purifier is connected by a coupling unit to a spindle which is suspended from a ball bearing assembly. The bowl is belt driven by an electric motor mounted on the frame of the purifier.

The lower end of the bowl extends into a flexibly mounted guide bushing. The assembly, of which the bushing is a part, restrains movement of the bottom of the bowl, but allows sufficient movement so that the bowl can center itself about its center of rotation when the purifier is in operation. Inside the bowl is a device consisting essentially of three flat plates equally spaced radially. This device is commonly referred to as the three-wing device, or just the three-wing. The three-wing rotates with the bowl and its purpose is to force the liquid in the bowl to rotate at the same speed as the bowl. The liquid

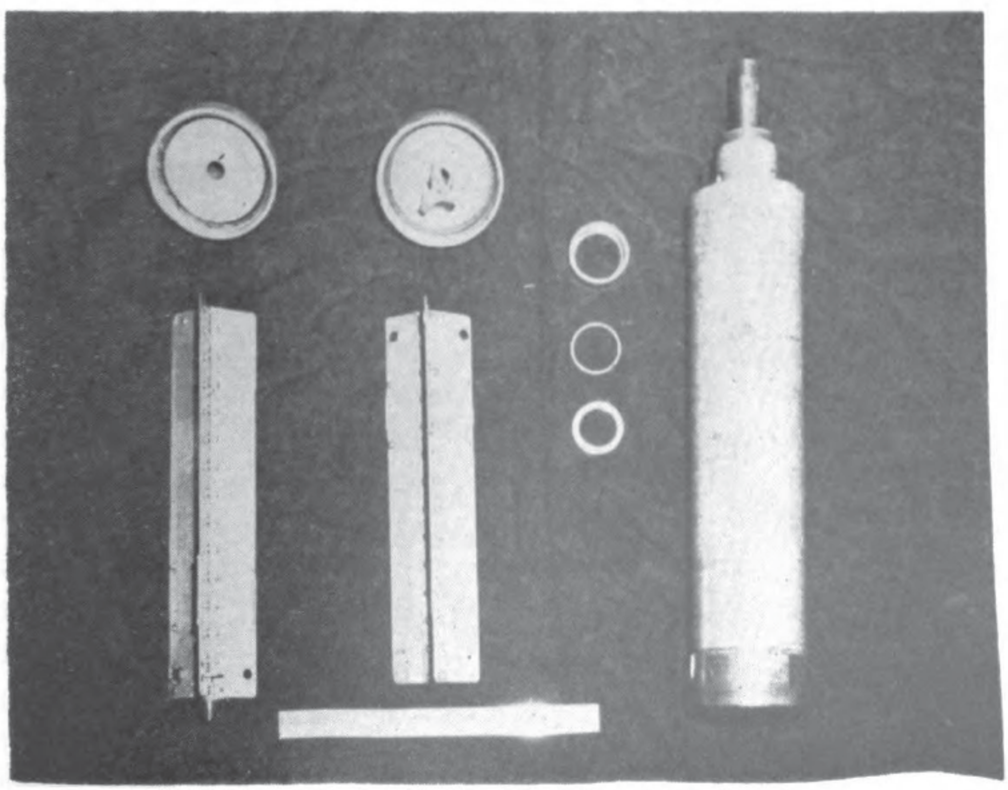


Figure 6–11.—Parts of a tubular-type purifier bowl.

to be centrifuged is fed into the bottom of the bowl through the feed nozzle under pressure so that the liquid jets into the bowl in a stream.

When the purifier is used as a lube oil clarifier, the three-wing has a cone on the bottom, against which the feed jet strikes in order to bring the liquid up to bowl speed smoothly without making an emulsion. Both types of three-wing devices are shown in figure 6–11.

In the tubular-type purifier, the process of separation is the same as in the disk-type purifier. In both types of purifiers, the separated oil assumes the innermost position and the separated water moves outward. Both liquids are discharged separately from the bowls while solids separated from the liquid are retained in the bowl (fig. 6–12). Even though similar in operation, the two types of purifiers differ somewhat in design features. By comparison, the bowl of a tubular-type purifier is of relatively small diameter and is operated at a relatively high speed.

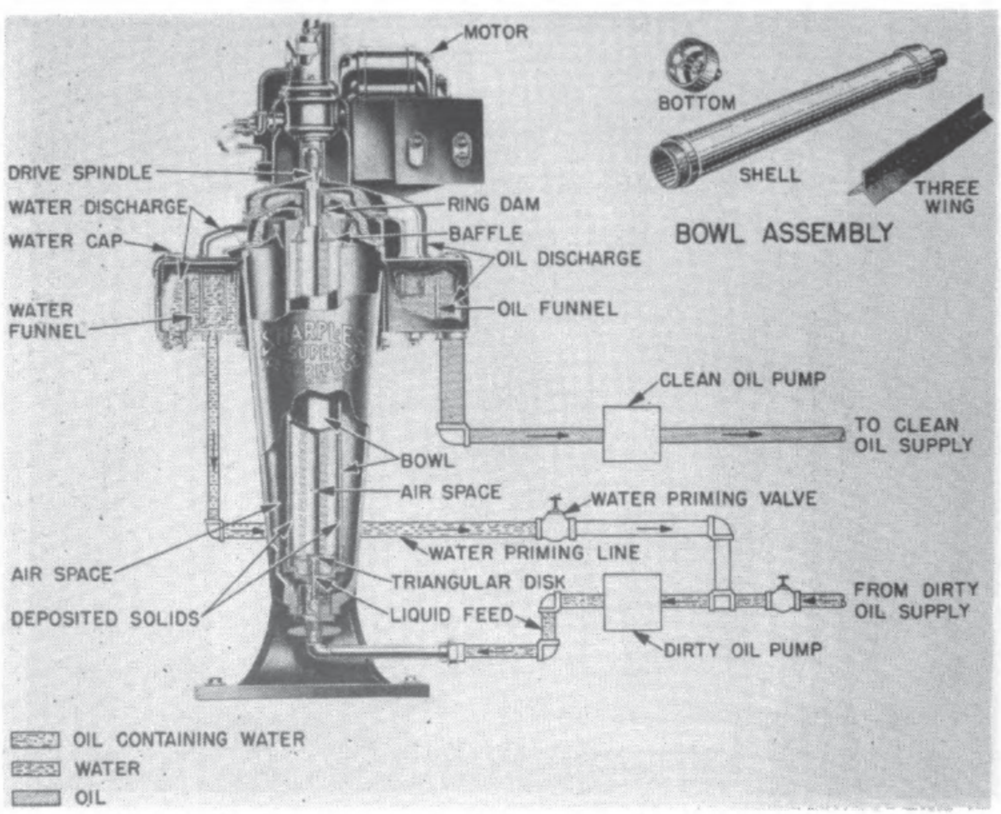


Figure 6–12.—Path of contaminated oil through a bowl-type purifier (Sharples).

The length of the tubular bowl (distance liquid travels through the bowl) is many times the depth of the liquid layer (settling distance). The disk-type bowl is characterized by a larger diameter and a much shorter length; in other words, the distance the liquid travels in passing through the bowl is not much greater than the settling distance. Tubular bowls are fed through a feed nozzle at the bottom of the bowl. Disk-type bowls are ordinarily fed from the top, through a center tube which directs the liquid toward the distribution holes in the disk stack.

General Notes on Purifier Operations

The specific details for operating a given purifier should be obtained from the appropriate instructions provided with the unit. Information provided here is, in general, applicable to both types of purifiers.

For maximum efficiency, purifiers should be operated at maximum designed speed and rated capacity. Since turbine oils are always contaminated with water of condensation, the purifier bowls should be operated as separators and not as clarifiers. An exception to operating a purifier at designed rated capacity is when a unit is used as a separator of 9000 series (compounded or additive-type heavy-duty lube oils) detergent oil. Some engine installations using oils of the 9000 series are exposed to large quantities of water. If the oil becomes contaminated with water, the oil has a tendency to emulsify. The tendency to emulsify is most pronounced when the oil is new, and gradually decreases during the first 50 to 75 hours of engine operation. During this period, the purifier should be reduced to approximately 80 percent of the rated capacity.

When a purifier is operated as a separator, PRIMING OF THE BOWL with fresh water is essential before any oil is admitted to the purifier. The water serves to seal the bowl and to create an initial equilibrium of liquid layers. If the bowl is not primed, the oil will be lost through the water discharge ports.

There are several FACTORS WHICH INFLUENCE PURIFIER OPERATION. The time required for purification and the output of a purifier depend upon such factors as the viscosity of the oil, the pressure applied to the oil, the size of the sediment particles, the difference in the specific gravity of the oil and the substances which contaminate the oil, and the tendency of the oil to emulsify.

The viscosity of the oil determines to a great extent the length of time required to purify lube oil. The more viscous the oil, the longer the time required to purify it to a given degree of purity. Decreasing the viscosity of the oil by heating is one of the most effective methods of facilitating purification.

Even though certain oils may be satisfactorily purified at operating temperatures, a greater degree of purification will generally result by heating the oil to a higher temperature. To accomplish this, the oil is passed through a heater where the proper temperature is obtained before the oil enters the purifier bowl.

Most oils used in Navy installations may be heated to a temperature of 180° F without adverse effects, but prolonged heating at higher temperatures is not recommended because of the tendency of such oils to oxidize. Oxidation results in rapid deterioration. In general, oil should be heated sufficiently to produce a viscosity of approximately 90 seconds, Saybolt Universal (90 SSU), but the temperature must not exceed 180° F.

Pressure should not be increased above normal in order to force a high-viscosity oil through the purifier. Instead, viscosity should be decreased by heating the oil. The use of pressure in excess of that normally used to force oil through the purifier will result merely in less efficient purification. On the other hand, a reduction in the pressure at which the oil is forced into the purifier will increase the length of time the oil is under the influence of centrifugal force, and therefore will tend to improve results.

If the oil discharged from a purifier is to be free of

water, dirt, and sludge, and the water discharged from the bowl is not to be mixed with oil, the PROPER SIZE DISCHARGE RING (RING DAM) must be used. The size of the discharge ring to be used depends upon the specific gravity of the oil being purified. All discharge rings have the same outside diameter, but have inside diameters of different sizes. Ring sizes are indicated by even numbers and the smaller the number, the smaller the ring size. The size, in millimeters, of the inside diameter is stamped on each ring. Sizes vary by two-millimeter steps. Charts, provided in instruction manuals, specify the proper ring size to be used with an oil of a given specific gravity. Generally, the size ring indicated on a chart will produce satisfactory results. However, if the recommended ring fails to produce satisfactory purification, it will be necessary to determine the correct size by trial-and-error. In general, the most satisfactory purification of the oil is obtained when the ring used is of the largest size possible without causing loss of oil with the discharged water.

Maintenance of Purifiers

The bowl of a purifier must be cleaned frequently and all sediment carefully removed. The frequency of cleaning depends upon the amount of dirt, grit, sludge, and other foreign matter in the oil to be purified. If the amount of foreign matter in an oil is not known, the machine should be shut down for examination and cleaning once during each watch, or more often if the condition of the system indicates that more frequent cleanings are necessary. The amount of sediment found in the bowl will give an indication as to how long the purifier may be operated between cleanings. The bowl should be thoroughly cleaned each time lube oil is run through for batch purification from the settling tank.

Periodic tests should be made to ensure that the purifier is working properly. Tests should be made at intervals of about 30 minutes when the oil in the system is being purified by the batch process. When the continuous process

of purification is used, tests should be made once a watch. While analysis of oil drawn from the purifier is the best method of determining the efficiency of the unit, general efficiency may be determined by observing the clarity of purified oil and the amount of oil in the separated water.

DETECTION OF LEAKS

In the lube oil systems, two types of leaks are encountered—oil leaking from the system or its units, and water leaking into the system or its units. Oil leaks can be detected by visually checking the various oil system units and piping, by an increase in oil consumption, and by the presence of oil in the bilges. Water leaks into the oil system can be detected by testing the discharge from the drain tanks and settling tanks; by noting the appearance of the oil purifier discharge; and by an increase in the reading of the gages attached to the drain tanks.

Inspections

You will be aided in detecting oil system leaks if you observe the following inspections:

1. HOURLY—note and log the amount of oil in the drain tanks.
2. DAILY—open the test cock on the oil cooler waterside and check for oil in the cooling water.
3. EACH WATCH—inspect the bilges for presence of oil; and the bearings, oil lines, and fittings for leaks.

QUIZ

1. What is friction?
2. What are the three types of friction?
3. What is the primary purpose of lubricating oil and grease? The secondary purpose?
4. What is the present accepted oil-film theory of lubrication?
5. Where are common soda soap greases used?
6. What are the three advantages of the graphite additive in graphite greases?

7. What is the viscosity of an oil?
8. What does a high viscosity index figure of an oil denote?
9. What is the fire point of an oil?
10. What is the demulsibility of an oil?
11. How can you tell from a Navy lube oil classification symbol what the viscosity of the oil is?
12. What does a viscosity of 80 mean?
13. If a forced-feed lubricating system pump is driven from the shaft of the lubricated unit, how is oil supplied to the system before the unit is started?
14. What is a settling tank?
15. What is the maximum allowable temperature rise of oil passing through bearings?
16. What precautionary temperature checks should be taken in a forced-feed lube system in addition to reading thermometers?
17. When should the lube oil strainers be removed and cleaned?
18. What three harmful effects are caused by water in the lube oil?
19. How are vents on tanks and gear casings a means of water contamination of lube oil?
20. What happens to lube oils when they are heated at high temperature for a prolonged period?
21. What are the two types of straight gravity-feed lubrication systems?
22. Why should the chains of chain-oiled bearings not be allowed to drag on the bottom of the oil well?
23. To what is the improper performance of a correct oil due?
24. What two types of centrifugal oil purifiers are used in the Navy?
25. How should the purifier bowl be operated when contaminated turbine oil is being centrifuged?

CHAPTER 7

CONDENSERS AND OTHER HEAT EXCHANGERS

Heat energy may be transferred by such units as condensers, coolers, and evaporators. Collectively speaking, these units may be called HEAT EXCHANGERS.

The purpose of a heat exchanger, as the name implies, is to transfer heat from one fluid to another fluid. In some instances a heat exchanger is used to carry away undesirable sensible heat (the heat energy of a substance), or to carry away latent heat and thereby change a vapor back to a liquid. In other instances, heat exchangers are used to produce two desirable effects simultaneously; that of removing heat from fluid in one part of a system, to produce a desired effect, and to add this heat to fluid in another part of the system to produce another desired effect. The fluids involved must always be at different temperatures, and the heat can flow only from the hotter to the cooler fluid.

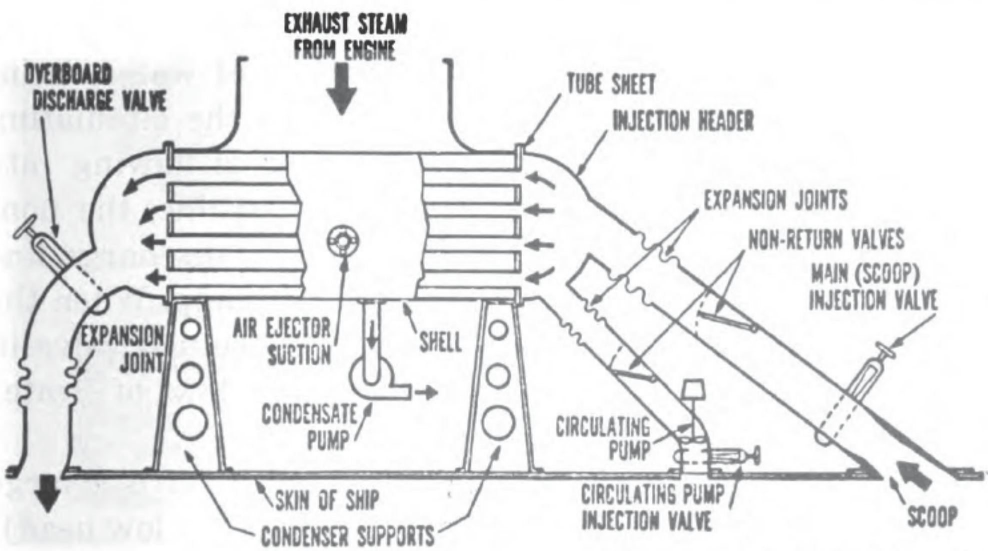
Since distilling plants, refrigerating plants, and air conditioning plants are discussed in other chapters of this text, and since the feed heating systems are of primary concern to the Boilerman rates, this chapter will be concerned with such heat exchanger units as you will encounter in the engineroom. These include the main and auxiliary condensers, air ejectors, air coolers, lube oil coolers, and deaerating feed tanks.

STEAM CONDENSERS

A condenser is a type of heat exchanger used to remove latent heat from vapor and thereby change a vaporized liquid back to a liquid. Since the main condenser of a steam plant is the plant's most important unit, the operation of this condenser will be discussed here in some detail.

Main Condensing System

A typical main condenser system is graphically illustrated in figure 7–1. This surface condenser has two separate and distinct circuits involved in the condensation of steam. The first of these is the vapor-condensate circuit in which the steam exhausted by the turbine enters the condenser at the top of the shell and comes into contact with the outside surfaces of the condenser tubes. The latent heat of steam is transferred through the tube walls to the flowing sea water inside the tubes and carried overboard. As its latent heat of vaporization is removed, the steam condenses on the tube surfaces. The condensate then falls to the bottom of the condenser, drains into the hotwell, from where it is removed by the condensate



Courtesy of U. S. Naval Institute

Figure 7–1.—Schematic arrangement of a main condensing system.

pump. Air and other noncondensible gases, which enter with the exhaust steam are drawn off by the air ejector through an AIR EJECTOR SUCTION OPENING in the shell, above the condensate level.

The second circuit is of course the cooling water circuit. During normal ahead operation, sea water flow through the condenser is provided automatically by means of the INJECTOR SCOOP. The scoop, which is open to the sea directs the water into the injection piping and forces it to flow on through the condenser. Since the condenser is located below the water line, a low rate of forward motion (4 to 5 knots) is sufficient to cause sea water flow through the condenser. STRAINER BARS (not shown in fig. 7–1) are installed in the sea chest or INJECTION PIPE inlet area to strain out sea weed and other debris which could foul the piping and condenser tubes. The injection line and discharge overboard lines are provided with expansion joints to prevent undue strains as a result of change in temperature or working of the ship's hull.

A main CIRCULATING PUMP provides cooling water through the condenser when scoop injection is ineffective, such as when a ship is stopped, backing down, or moving ahead at very slow speed. A large SWING CHECK, or NONRETURN VALVE, which prevents back flow of water, is installed in the main injection line and in the circulating pump discharge line. Thus, when water is flowing into the condenser through the main injection line, the nonreturn valve in the main circulating pump discharge line prevents back flow of water through the pump. When the circulating pump is in operation, the nonreturn valve in the main injection line prevents back flow of water through that line.

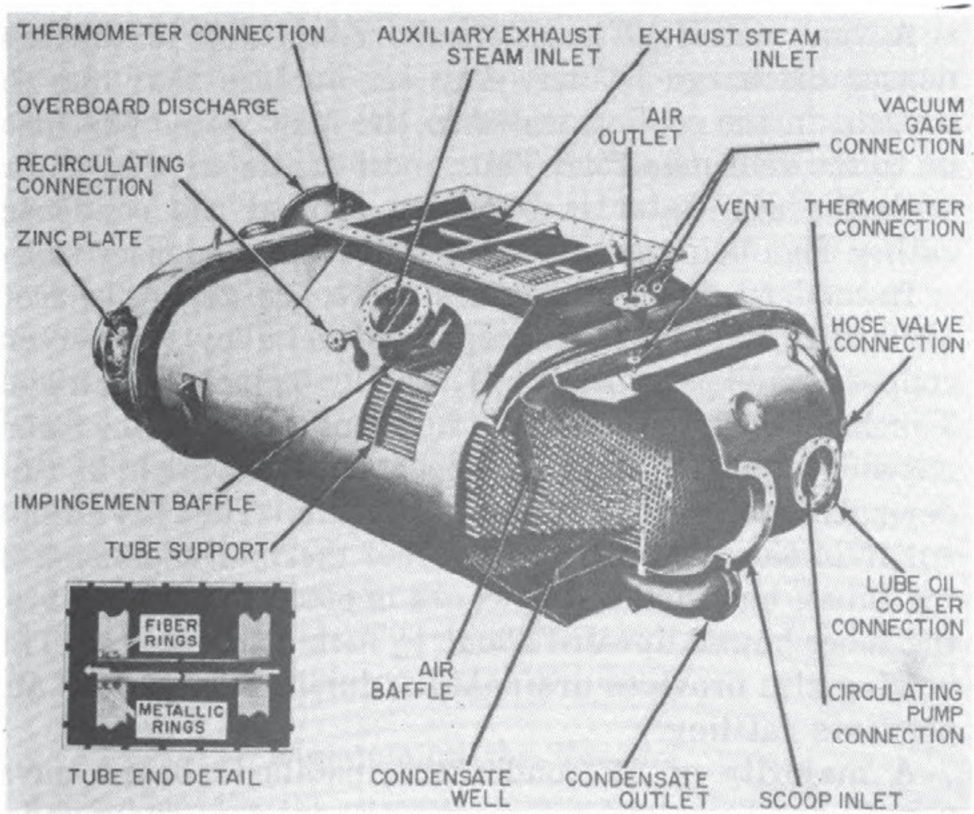
In all cases, the circulating pump must have a large capacity (as high as 30,000 gpm against a very low head). The pump is usually of the propeller type. The main circulator can also be used for pumping water overboard

via the bilge injection (suction) line should there be serious flooding of the engineroom.

Construction Features of A Condenser

To ensure proper maintenance of a condenser, there are certain installation and construction features which you should understand. Modern installation practice is to suspend the condenser from the turbine rather than to have the condenser support the turbine. This allows for a greatly reduced weight, and makes it unnecessary to use an expansion joint between the turbine and the condenser.

You may get a general idea of the condenser's construction, including the location of its principal parts, by studying figure 7–2. The HEADERS are usually made of nickel-copper alloy, and are wiped on the inside with solder made up of 2 parts lead and 1 part tin. The inside water surfaces are smooth (except for ZINCS and THERMOMETER



Courtesy of Westinghouse Electric Corp.

Figure 7–2.—Cutaway view of a main condenser.

WELLS), to afford a streamlined water flow with a minimum of eddies. MANHOLES are provided in each header for access to the water space for the purpose of inspecting and cleaning the tube-sheets. The TUBE-SHEETS serve as partitions between the salt water and fresh water or steam. They are flat end plates made of copper-nickel alloy and hold the tube ends. ZINC PLATES are attached to MANHOLE COVERS to protect condenser parts from the effects of galvanic action by the sea water. The studs, nuts, and washers holding the zinc plates are made of chrome-copper alloy to provide for high electrical conductivity. The plates are corroded by electrolytic action. This protects other surfaces from similar corrosion as long as there is zinc available and as long as there is good metal to metal contact between the zincs and the headers, tube sheets, and tubes. The manhole covers also provide access for inspecting and cleaning the condenser tubes.

A vent manifold is externally connected to the condenser discharge header. Any air bubbles that may be present in the cooling water in the inlet water box, pass on to the vent manifold. Thus, most of the air that enters with the sea water is bypassed around the condenser rather than being permitted to enter the condenser tubes.

In modern main condensers there are generally from 6000 to 10,000 TUBES of a copper-nickel alloy (70 percent copper and 30 percent nickel), usually 5/8 inch in diameter. The length of the tubes and the number of the tubes depends upon the size of the condenser, which in turn depends upon capacity requirements. The EXPANSION JOINT in the shell allows for some thermal expansion of the tubes, but further allowance is often made by having the tubes bowed upward about 1/2 inch at the center. This bowing also provides drainability during idle periods and prevents rattling.

A majority of all condensers installed aboard naval vessels have straight tubes with the inlet ends expanded in the tube holes in the tube sheet. The inlet expanded

tube ends are flared to prevent the formation of eddy currents. In many installations, the outlet tube ends are also expanded. Flexible metallic packing is used for packing the outlet ends of some condenser tubes. It should be noted that the outlet ends of packed tubes must not be expanded or flared. The outlet ends of these tubes may extend about $\frac{1}{16}$ inch from the face of the tube sheet or may be milled flush with the tube sheet surface.

Condensate forms on contact with the cold tubes and drips down below the tubes, collecting in a HEATING TRAY.

From this tray, the condensate drains into the HOT WELL which serves as a sump for the CONDENSATE PUMP suction. The heating tray serves to raise the condensate temperature from the sea water temperature of the tubes to near the temperature of the exhaust steam.

Baffles divide condensers into four air cooler sections. The four sections are connected by pipes through which all air to be exhausted must pass to the air suction connection at the top of the condenser. The lower portion of the condenser is baffled lengthwise to prevent surging of the condensate from one end to the other. Sealing plates are welded to the bottom of the condenser throughout its length to prevent the free flow of steam into the air coolers. The condensate collecting tray is installed between each group of condenser tubes and is formed by longitudinal baffle plates welded to the bottom of the condenser. These plates have serrated top edges and are divided into small compartments by transverse baffles. This allows a steady flow of water into the hot well while maintaining a seal of 3 inches of water in each compartment unless the ship lists more than 15 degrees. A more detailed description of the condenser's construction can be found in the respective manufacturer's manual, and in chapter 46 of *Bureau of Ships Manual.*

Maintaining the Vacuum

Under conditions of warming up, standing by, getting under way, cooling down, and securing of the main en-

gines, the condenser vacuum should be regulated in accordance with information given in the chapter on turbine operation in this manual, the manufacturer's instruction book, and any operating standards pertaining thereto.

Two basic rules that apply to the operation of single-pass main condensers should be kept in mind. The first is that the OVERBOARD TEMPERATURE should be about 10° higher than the INJECTION TEMPERATURE. The second rule is that the CONDENSATE TEMPERATURE should be within a few degrees of the EXHAUST TEMPERATURE.

The EXHAUST TEMPERATURE varies with the vacuum. Below is a table of approximate values, based on a 30.00-inch barometer, showing exhaust temperatures corresponding to vacuums you normally use.

Inches of vacuum	*Temperature °F*
29.6	53
29.4	64
29.2	72
29.0	79
28.8	85
28.6	90
28.4	94
28.2	98
28.0	101
27.8	104
27.6	107

Scoop injection systems are designed to provide a maximum amount of cooling water at cruising speeds, with injection and overboard valves wide open, and a sea water temperature of about 70 degrees. Ordinarily it is not necessary to control the CIRCULATING WATER FLOW by throttling the valves. If it becomes necessary to do so, due to operating in cold water or under unusual conditions, the proper valve to use is the overboard valve. If the inlet valve is used, a turbulence will be created in the condenser and eventually this turbulence will cause erosion of the tubes. Therefore, it is advisable to use the overboard

valve to eliminate the turbulence problem and to ensure flooded tubes.

If the condenser vacuum is not as high as it should be, in relation to condenser load and cooling water overboard temperature, something in the condensing system is not functioning properly. You may find, for example, that the air ejectors are not properly removing air from the condenser, that the condensate pump is not keeping the right condensate level, or that there are some air leaks in the condenser or in some other part of the system.

The CONDENSATE LEVEL should be kept as low as possible and care must be taken not to allow the level to rise out of the hotwell and into the condenser shell. Allowing the level to rise slightly higher than the top of the hotwell will cause the condensate temperature to be less than normal because the path for the flow of "reheating steam" will be partially blocked by the condensate. (Reheating steam refers to steam which enters the hotwell via the central steam lane. The central steam lane extends completely through the tube bundle and provides for longitudinal distribution of steam from the exhaust inlet directly to the condenser hotwell.) If the condensate level is allowed to rise up to the bottom row of tubes, the flow of reheating steam will be further restricted, causing an even greater drop in condensate temperature. At this point, also, the condensate level will begin interfering with the flow of air toward the air removal areas, thus causing a gradual loss of vacuum. A rapid loss of vacuum, accompanied by a rapid increase in condenser shell temperature and exhaust trunk temperature, will result if the condensate level rises up to the lower end of the air baffles. This results not only because air removal ceases, but also because a large part of the tube bundle will be submerged and not available for cooling and condensing the incoming steam. If the condensate level rises and cannot be brought down to normal immediately by speeding up the condensate pump or by cutting in an additional pump, the turbine speed

must be reduced to avoid serious damage to the engine and condenser.

Circulating Water Flow

An adequate flow of circulating water must be provided continuously to an operating condenser. This circulating flow maintains the required vacuum and prevents the condenser from becoming overheated to a point where the steam pressure could build up to the point of explosion. The flow must be adjusted in accordance with the temperature of the water, the operating conditions, and the vacuum desired in the condenser.

CAUSES OF INSUFFICIENT CIRCULATING WATER are:

1. Condenser tubes clogged with foreign matter, such as fish, sea weed, or mud.
2. Obstruction of injection or discharge sea chests, strainers, piping, or valves with foreign matter.
3. Injection or overboard valves not properly adjusted.
4. Inefficient or inoperative circulating pump.
5. Obstructed air vents.
6. Faulty nonreturn valves in scoop injection or circulating pump.
7. Distortion of injection or discharge sea chest strainer bars, plates, or projecting lips, due to grounding or collision.

STEAM OR AIR CONNECTIONS are provided to clear foreign matter from sea chests. Sometimes, however, thick growths of grass rooted on or around sea valve openings cannot be blown clear. In such cases, as well as when maximum pressure fails to clear a strainer, the obstruction must be removed by a diver. Not infrequently, schools of fish have been scooped into a condenser header, making it necessary to remove a manhole and shovel out the extraneous material.

AIR VENTS MUST BE KEPT OPEN under all operating conditions where the vents are piped overboard through the hull, or where the inlet water chest is vented to the discharge water chest or piping, to minimize air erosion of

the tubes, and to avoid air-binding. Vents that are piped to the bilge should be kept slightly open at all times when the condenser is in use. As long as a trickle of water escapes, the unit cannot become air bound, and the circulating water flow will not be obstructed.

Most main condenser circulating pumps are provided with BILGE SUCTION CONNECTIONS. These condenser circulating pumps generally constitute the largest potential capacity available for pumping engineroom bilges, and it is important that you know how to make necessary connections to these suctions in cases of emergency. It is usually necessary only to turn the bilge suction line stop or stop check valve a fourth to a third of the way open, or until the maximum bilge suction capacity is obtained.

As already indicated, the TEMPERATURE OF THE CIRCULATING WATER has a direct influence on the maximum vacuum obtainable in the condenser. Small changes in temperature will generally adjust themselves, with relation to change in steam temperature and vacuum variations; large variations are detrimental to the efficiency of the condenser.

Sea Water Leakage

Leakage of sea water into the condensate through one damaged tube, out of the thousands in use, will contaminate the feed water. Sea water leakage into the system is serious; the entire engineering plant may salt up and become badly damaged as a result.

You may learn that a leak exists by watching the SALINITY INDICATOR described in chapter 10. The indicator, usually located at a position convenient to the main control station in the engineroom, must be kept in operative condition at all times. Salinity cells must be checked frequently by the chemical method described in chapter 10. When the salinity reading goes above normal, action should be taken as soon as practicable to determine the cause. If the salinity gage pointer is in the RED, it is time for ACTION. You must notify the Officer of the Watch (OOW) without delay.

If the engineer officer then decides to shut down the condenser and main engine for a tube inspection, your first task is to locate the leaky tube or tubes. This is usually done by putting 5 psi air pressure on the steam side of the tubes, then observing where the air blows out on the water side. The condenser is slowly filled with water from a fire hose until bubbles show the exact locations of the leaks. The faulty tubes are then plugged.

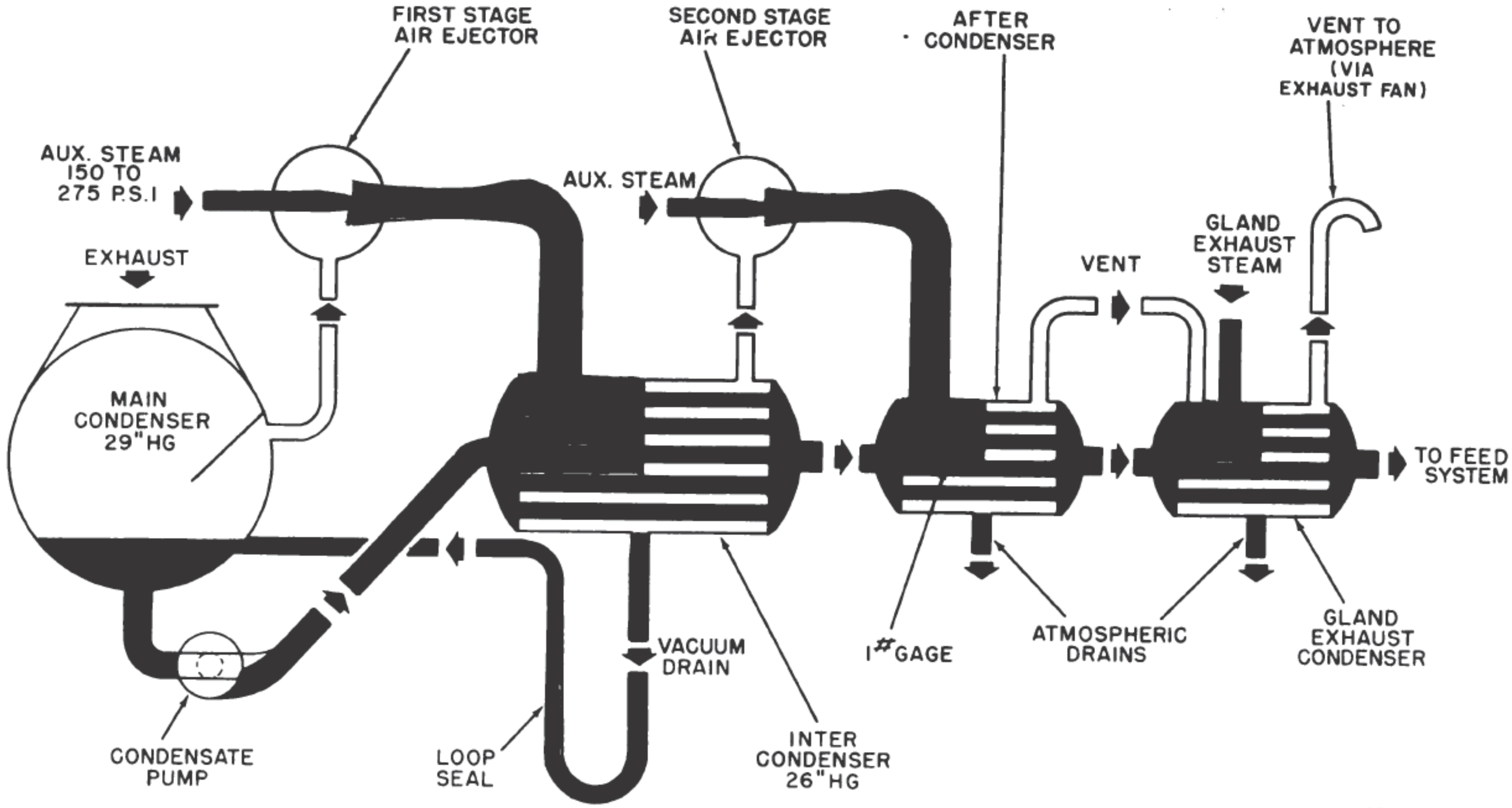
The faulty tubes should be plugged at each end with metal or phenolic tube plugs; these plugs are furnished to each vessel by the manufacturers of the main condenser. If phenolic tube plugs are used, they should conform to specification MIL–P–15742. Plugs should be driven firmly into the ends with light hammer blows. If it becomes necessary to plug tube sheet holes after a tube has been removed, it is good practice to install short sections of a tube in the tube holes and secure them by expanding prior to inserting tube plugs; this will protect the tube holes from damage. Plugged tubes should be renewed at a naval shipyard during the next availability for the vessel, if water chests are removed for other work.

AIR EJECTORS

The function of an air ejector is to remove air and other gases from the condenser. An air ejector is a type of jet pump, containing no moving parts. The flow through the air ejector is maintained by a jet of high-velocity steam passing through a nozzle (fig. 7–3).

The air ejector assembly used to remove air from the main condenser consists of a first-stage air ejector, an inter-condenser, a second-stage air ejector, and an after-condenser. The entire assembly is usually referred to as an AIR EJECTOR.

The first-stage air ejector takes suction on the main condenser and discharges the steam-air mixture to the inter-condenser, where the steam content of the mixture is condensed. The resulting condensate drops to the bottom of the inter-condenser shell, and from there drains



Courtesy of U. S. Naval Institute

Figure 7–3.—Flow diagram of a two-stage air ejector.

to the main condenser through a U-shaped loop seal line. The air passes to the second-stage air ejector suction.

In the second-stage air ejector, another jet of steam is used. The steam-air mixture is now discharged into the after-condenser, where the steam is condensed and the air is vented to the atmosphere. (Normally, the air is vented to the atmosphere by way of the gland exhaust condenser; however in some installations it is vented directly to the atmosphere from the air ejector after condenser.) The second-stage air ejector actually does most of the work in maintaining the vacuum on the main condenser.

Condensate from the main condenser is used as the cooling water in the air ejector inter- and after-condensers. It is important to note that this is the ONLY reason why condensate passes through the air ejector condenser. The air ejectors remove air only from the condenser, not from the condensate.

The inter-condenser is under vacuum of about 26 inches of mercury. The after-condenser is at approximately atmospheric pressure.

To assure sufficient cooling water for proper operation of the air ejectors when raising vacuum, standing by, and at fractional power (cruising), a condensate recirculating line and valve are installed at the cooling water outlet from the after condenser or on the feed water outlet of the deaerating feed tank. To make recirculation automatic, and to avoid excessive recirculation with attendant excessive loss of heat, most air ejector recirculating lines are fitted with thermostatically controlled valves.

Excessive heat loss can be avoided by recirculating condensate from the air ejector outlet line back to the main condenser. A hand-controlled valve allows bypassing of the thermostatic recirculating valve during the warming-up period. This bypass valve is also used in case the thermostatic valve is inoperative. When the required condenser vacuum is obtained, the manually controlled bypass valve is secured.

Under normal operating conditions, recirculation to the

main condenser at light loads is automatically controlled by the thermostatic recirculating valve.

Operating an Air Ejector

Operating instruction books are furnished to provide for the proper operation of all air ejector installations. The general procedure for STARTING THE AIR EJECTORS, however, is somewhat as follows:

1. Drain the steam supply lines to the air ejector assembly.
2. Start circulation of condensate cooling water in the inter- and after-condensers.
3. Open the valves in the drain lines, from the inter- and after-condensers.
4. Check the valves in the pressure and vacuum gage lines to be sure they are open.
5. Be sure the atmospheric vent line is clear of condensate pockets.
6. Open the suction and discharge valves of both first and second stages.
7. Open the steam valve to the second stage, and check the steam pressure to ensure it is at, or above, the designed pressure.
8. When the condenser vacuum rises to or above 20 inches, open wide the steam valve to the first stage unit.

Upon completion of the preceding procedure, the ejector should be in full operation, and the main condenser vacuum should rapidly rise to that obtainable under stand-by conditions.

Inter-stage valves should always be opened before admitting steam to the ejector nozzles, and the steam supply to the nozzles should always be shut off before closing the inter-stage valves at the discharge of the ejector elements.

Very little attention is required after the ejector has been properly started. It is necessary only to:

1. Supply dry steam at proper operating pressures.
2. Provide a sufficient flow of cooling water through the inter- and after-condensers.
3. Maintain a proper drainage of the inter- and after-condensers, and of the steam line to the ejector.

Shifting Ejectors

Should it become necessary or desirable to shift from one two-stage ejector unit to another while the air ejector unit is in operation, the procedure is as follows:

1. Open the discharge valve (if provided) of the standby second-state ejector and see that the after-condenser drain line is clear.
2. Open wide the second-stage steam inlet valve.
3. Open wide the second-stage suction valve. When this is done, the standby second-stage unit begins to take suction from the inter-condenser along with the other second-stage element.
4. Open the first-stage discharge valve (if provided) of the standby element. See that the valve in the inter-condenser drain line is open.
5. Open wide the steam inlet valve to the first-stage nozzle.
6. Open wide the suction valve of the first-stage element. At this point both two-stage elements are in operation in parallel.
7. Secure the suction valve of the first-stage element to be secured.
8. Secure the steam supply valve to this first-stage element.
9. Secure the suction valve of the second-stage element to be secured.
10. Secure the discharge valve (if provided) of the first-stage element.
11. Secure the steam supply valve of the second-stage element.
12. Secure the discharge valve (if provided) of the second-stage element.

This completes the operation. If the turbine unit and consequently the condenser is operating at a low or medium rate when the elements are shifted, it may be necessary to recirculate condensate during the time when both two-stage elements are in service in order to provide sufficient cooling water for the inter- and after-condensers. If insufficient cooling water is provided, or if the valves are opened and closed in the wrong order, a loss of vacuum will result, and there is a possibility of putting excessive pressure on the air ejector condensers and diffusers.

Securing an Air Ejector

When securing an air ejector assembly, proceed as follows:

1. Close the first-stage suction valve.
2. Close the first-stage steam inlet valve.
3. Close the second-stage suction valve.
4. Close the first-stage discharge valve (if provided).
5. Close the second-stage steam valve.
6. Close the second-stage discharge valve (if provided).
7. Leave the drain lines open in order that no pressure will build up, should a steam inlet valve leak. Should steam back up through the after-condenser drain line when the unit is secured, it is permissible to close the drain after ascertaining that the steam inlet valve is tight, and that the sentinel and relief valves on the air ejector assembly are in proper operating condition.

Care and Maintenance of Air Ejectors

If an air ejector fails to maintain the proper main condenser vacuum, the cause may be traced to one of the following difficulties:

1. FAULTY STEAM PRESSURE.—If the pressure fluctuates and falls below standard, raise it to a point not over 15 psi above the designed pressure. Too high a pressure can also cause a reduced capacity, may overload the con-

denser units, and will necessitate an uneconomical quantity of steam.

2. CLOGGED STEAM STRAINERS.—Strainers provided ahead of the nozzles must be clean, and inspected semi-annually.

3. INSUFFICIENT COOLING WATER.—If enough cooling water is not circulated through the two condenser units, a loss in vacuum results. This happens because the water becomes heated and will not condense the steam content of the air-vapor mixture entering the inter-condenser. The second-stage ejector becomes overloaded, because instead of handling only saturated air it must also handle some of the uncondensed steam discharged into the inter-condenser from the first-stage ejector element. Watch the temperature of the cooling water at the cooling water outlet, and keep it at the temperature designated by the manufacturer.

4. UNLOADING VALVE.—Two stage air ejectors are all about the same size and capacity because the amount of air that must be removed does not vary a great deal from one steam condensing system to another. However, the amount of condensate that is handled in the different systems does vary. For example, the volume of steam passing through a turbine and the consequent resulting condensate, in a battleship operating at full power, are much greater than in an auxiliary ship's turbine, operating at full power. In high power ships, in order to take care of condensate flow in excess of the amount that can pass through the cooling section of an air ejector unit, as occurs at high power rates, a bypass arrangement is provided so that condensate (cooling water), in excess of the air ejector needs, is led directly to the feed heating tank. This bypass is provided with a spring loaded valve, usually referred to as an UNLOADING VALVE. When condensate is flowing at a low rate, a spring holds the valve closed; thus all condensate passes through the air ejector cooling sections. When the rate of condensate flow is so great that a back pressure is built up at the air ejector

cooling water inlet, the increased pressure in the condensate line overcomes the spring tension of the unloading valve; thus this valve automatically allows condensate in excess of that needed for cooling the air ejector to go directly to the feed heating tank. In other words, the condensate follows the path of least resistance. In new high-powered ships, the air ejector is sized to handle the full condensate flow and no unloading valves are provided.

5. LEAKAGES.—Air leaks through the suction or discharge valves of ejector elements result in a loss of vacuum due to overloading of the elements. Leaks in valve glands, gasketed joints, relief or sentinel valves, etc., will have the same results.

Flooding of the inter- or after-condenser shell with condensate due to leaking tubes in the inner or outer condenser, or due to improper drainage will interrupt the removal of air and cause loss of vacuum.

Tube joint leakages can be remedied by repacking the tube ends with copper-asbestos packing rings. For detailed information about methods for repair of leaks, refer to the pertinent manufacturer's instruction book and to chapter 46 in the *Bureau of Ships Manual.*

6. FOULED NOZZLES.—Erosion or fouling of air ejector nozzles is evidence that wet steam is being admitted to the equipment. The faulty nozzles make it impossible to operate the ejector under high vacuums. In some instances, the nozzles may be clogged with grease, boiler compound, or some other deposit which will decrease the jet efficiency. If there are grease deposits, a soaking in carbon tetrachloride may aid in cleaning the nozzles.

7. UNSTABLE LOOP SEAL.—An air leak in the U-shaped loop seal provided for draining the inter-condenser will result in an unstable seal. Occasionally a sudden surge in vacuum or a violent roll of the ship may cause the water in the seal to siphon out into the condenser. In this case, close the valve at the condenser end of the loop seal for a few seconds and then open slowly as the seal

becomes established. A connection on the condensate line is usually provided for filling the seal.

GLAND EXHAUST CONDENSER

In order to recover the steam expelled by the turbine glands, a gland leak-off and vent and drain system is installed. By means of this system the recovered steam is returned to the feed system in the form of condensate. The gland leak-off steam is led to the GLAND EXHAUST CONDENSER where the vapors are condensed and led to the fresh-water drain collecting tank. Noncondensible gases are drawn off from the gland exhaust condenser via a gland-exhaust fan which discharges in the vicinity of a ventilation exhaust opening.

DEAERATING FEED TANKS

The deaerating feed tank (fig. 7–4) serves to heat, deaerate, and store feed water. This tank figuratively "scrubs" the feed water free of air by the use of spray nozzles. The water is heated in the deaerating tank by direct contact with auxiliary exhaust steam. The auxiliary exhaust steam pressure is approximately 2 psi higher than the pressure in the deaerating tank. The deaerating tank is usually designed to operate at a pressure of approximately 10 to 15 psig, and to heat the water to between 240° and 250° F. The water is kept just under its boiling point at the operating pressure, so that it will not flash into steam.

Condensate enters the deaerating feed tank through the tubes of the vent condenser; it is forced out through a number of spray valves in the spray head, and is discharged in a fine spray throughout the steam-filled upper section of the deaerating tank. The tiny droplets of water are heated and scrubbed by the relatively air-free steam, so that practically all of the dissolved air is released. The drops of water fall through the steam-filled atmosphere and are collected in a cone-shaped baffle which leads them, through a central port, to a deaerating unit.

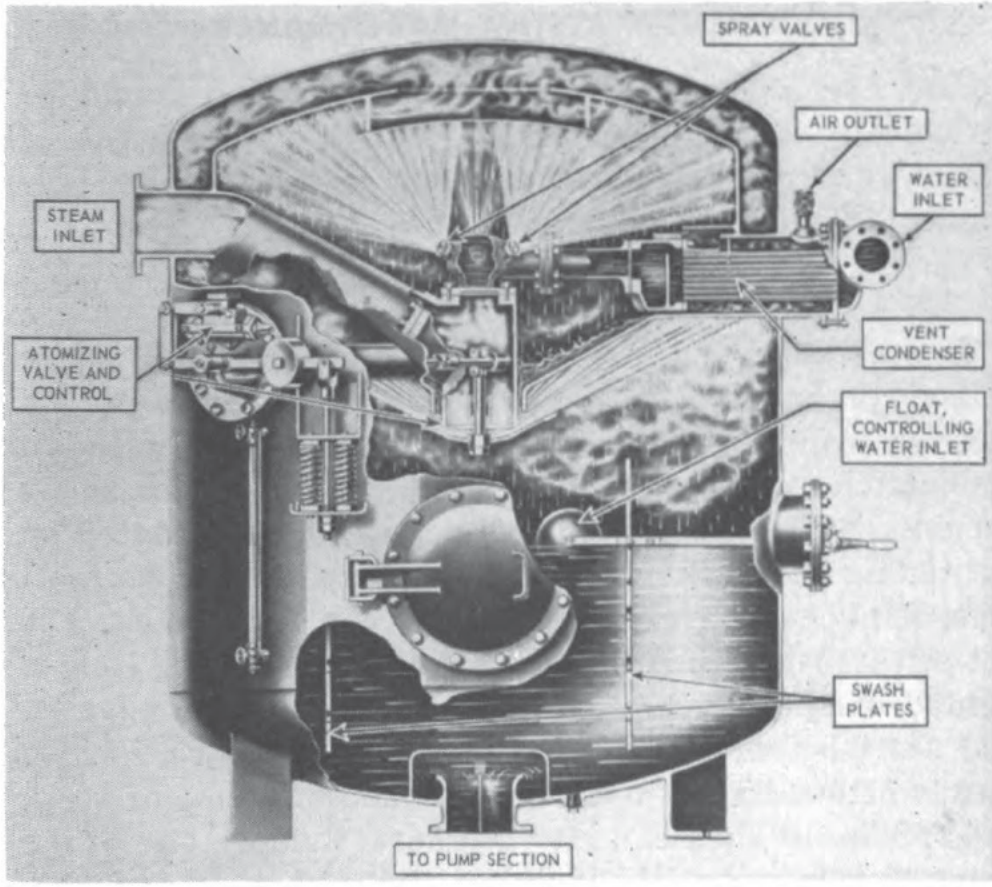


Figure 7–4.—Direct-contact deaerating feed tank.

By this time, the water has been partially heated and partially deaerated. Further deaeration occurs as the steam coming into the deaerating unit picks up the water and throws it radially outward and upward against the lower side of the conical baffle. In this process, the water and steam are so thoroughly mixed that the water is heated to practically the same temperature as the steam. The deaerated water then falls into the storage space at the bottom of the tank, where it remains under a blanket of air-free steam until it is needed for the boilers.

Steam sweeps the air from the deaerating feed tank. The mixture of steam and air travels across the vent condenser tubes, where some of the steam is condensed into water which is fed back into the deaerating tank. The air and any remaining steam go to the gland exhaust condenser.

CONDENSER SYSTEM MAINTENANCE

Heat exchangers and associated equipment should be periodically inspected to ensure that they are operating efficiently. Preventive maintenance is much more economical than corrective maintenance.

Air Leaks

To maintain the desired condenser vacuum, there must be no leaks in the unit. Leaks at flange joints and porous castings can usually be stopped temporarily with an application of shellac when the condenser is under vacuum. Leaks around valve stems can be eliminated by tightening the packing. Small leaks around porous castings, flange nuts, valve stems, etc., can sometimes (but not always) be located by the candle-flame test. Hold a lighted candle close to areas where leaks are suspected and see whether the flame will flicker. A more reliable means of locating condenser air leaks is by use of soapsuds while the shell is under pressure. Remove one of the thermometer wells and install a pressure gage and line. Now subject the condenser shell to a pressure of 5 psi. Apply soapsuds to the units and areas where a leak is suspected and watch for the formation of bubbles.

All places where it is possible for an air leak to exist should be investigated. Some of the places to look for possible leaks include the following:

1. Make-up feed line.
2. Vacuum gage lines.
3. Absolute pressure gage line.
4. Drain collecting system drain line.
5. Air ejector intercondenser drain line.
6. Condensate pump suction line, vent line, and gland sealing system.
7. Condensate and vent lines under vacuum.
8. Air-removal suction line.
9. Thermometer connections.

10. Main exhaust flange and turbines exhaust trunk manholes.
11. Fittings with porous castings.
12. Shell relief valve.
13. Evaporator drain line.
14. Boiling-out connection at bottom of shell.
15. Drain connections or plates at bottom of hotwell.
16. Hotwell gage glass and fittings.
17. Auxiliary exhaust dumping line.
18. Turbine drain lines.
19. Condensate recirculating line.

Care of Zinc Plates

Zinc protectors lose their full effectiveness if the decomposed metal is not removed from their surfaces, or if they are deteriorated to the extent that there is an appreciable reduction in exposed surface area. In order to provide maximum protection against damage to condensers through electrolysis, protective zincs must be inspected and thoroughly scaled at intervals not exceeding one month. Zincs that are found to be more than one-half deteriorated must be replaced. Figure 7–5 shows how a badly scaled zinc plate appears before and after the scaling or cleaning process.

Cleaning the Condensers

Foreign matter lodged on the steam condensate water side of the condenser tubes interferes with and reduces the rate of the flow of heat from the condensing steam to the circulating water. This, in turn, reduces the maximum vacuum obtainable, and lowers the efficiency of the condenser. The lodgment of foreign matter on the sea water side of the tubes is detrimental to the tubes themselves in addition to slowing down the transfer of heat. Frequent visual inspections provide the only safe means of knowing the conditions of condenser fouling.

Grease and dirt on the STEAM SIDE of a condenser may be boiled out with a strong solution of boiler compound,

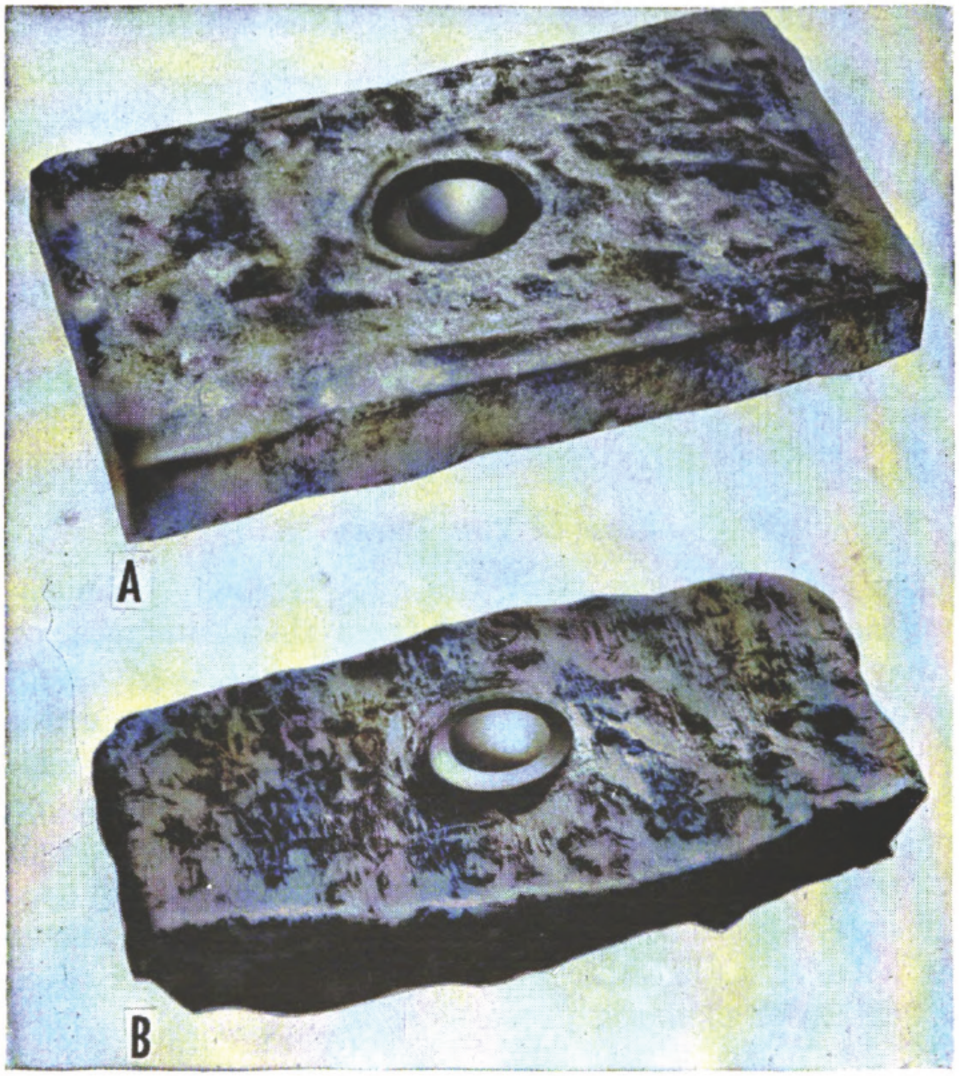


Figure 7–5.—Badly scaled zinc plate: (A) before being cleaned, and (B) after being cleaned.

or may be removed by soaking with a 0.5 percent by volume solution of wetting agent (Stock No. G6850–282–9702) heated to approximately 150°F. Normally, though, this boiling-out process should not be necessary oftener than once every 2 or 3 years.

The SEA-WATER SIDE of the tubes should be cleaned as often as necessary; the intervals depending upon the rate at which slime, marine growth, scale, mud, oil, grease, etc., are deposited on the tube walls. The amount of such deposits depends upon existing conditions. Operation in

shallow water, for example, may cause this fouling of the tubes. For ordinary cleaning, the tubes can be scrubbed out with a rotating bristle brush, or an air lance may be pushed through them. Another method is to shoot soft rubber plugs (fig. 7–6) through the tubes by means of compressed air or water under pressure.

Figure 7–6.—Typical rubber plugs used for cleaning inside of condenser tubes.

Care of Idle Condensers

An idle condenser should ordinarily be kept dry in its sea-water side. In rare instances, where corset lacing and ferrules (tube-shaped bushings) are employed for packing tube ends, the idle condenser should be kept filled and circulated daily. If, on the other hand, the condenser is to be put into active use again in a few days, it may be kept filled and circulated daily. An exception is taken to this latter practice when the ship is lying in highly polluted water. The steam side of the condenser should always be dry when the condenser is secured.

CONDENSER OPERATING INSTRUCTIONS

Prior to raising vacuum in the condensers, inspect to see that headers are not leaking and that the drains are closed in the circulating water system. All steam drains should be closed. All circulating pump bearings should be inspected for proper lubrication. Be sure to drain the line ahead of the unloading valves, otherwise

the condenser tubes might be damaged by the jet action of the steam and water.

Raising Vacuum

1. Start the circulating water pump to begin water circulation through the tubes. Crack the vents in the headers to determine if the condenser is air-bound.

2. Start the condensate pump as soon as sufficient condensate shows in the hotwell sight gage. (If there is insufficient condensate in the hotwell, open the hot recirculating valve at the bottom of the deaerating tank. This will permit warmed condensate to flow into the condenser.) Recirculate the condensate to give the air ejector cooling water.

3. Start the vent fan in the air ejector discharge vent.

4. Cut in steam to seal the turbine glands.

5. Cut in steam to start the second stage of the air ejector and operate in accordance with the design pressure given on the nameplate.

6. Cut in steam to the first stage of the air ejector when the vacuum in the system reaches 20 inches of vacuum.

Securing

The following procedure should be followed for securing a main condenser:

1. When the order to secure has been received, and the throttle has been closed, reduce the vacuum by securing the first stage steam to the air ejector.

2. Start the auxiliary condenser and cut in auxiliary exhaust.

3. Secure the second stage steam to the air ejector by securing the steam supply valves. This breaks the vacuum.

4. After the vacuum has dropped to 10 inches, secure the gland seal steam.

5. Secure the gland exhauster.

6. Pump down the main condenser until the water level can be observed in the hotwell—then secure the condensate pump.

7. Circulating (salt) water should be pumped through the condenser for at least three-quarters of an hour even though the exhaust trunk temperature drops below 90° —then secure the circulating pump.

CONDENSER SAFETY PRECAUTIONS

The following safety precautions should be observed in relation to all steam condensers in the engineering plant:

1. Make every effort to eliminate air leaks through entire system under vacuum.

2. Do not subject sea-water chests to pressures in excess of 15 psi.

3. Lift by hand and examine water chest relief valves whenever condensers are secured.

4. To detect salt water leaks, run salinity tests every 15 minutes while under way, and every 30 minutes while at anchor.

5. Keep baffle plates in place under steam inlets to condensers, and keep them in good condition.

6. Keep an adequate number of zincs in place, and ensure that they always have good metallic contact.

7. Slow down or stop engine, if a loss of vacuum is accompanied by a hot or flooded condenser.

8. Keep water from accumulating in the condenser and overflowing into the turbines or cylinders of engines.

9. Keep condensers clean and tight.

10. Before the salt water side of a condenser is opened, close all sea connections tight and secure them against accidental opening.

11. Bring no open flame (or anything which will cause a spark) close to a newly opened condenser, until it has been thoroughly blown out with steam or air. Hydrogen or sewer gas may be present.

12. Renew deteriorated tube packings before they reach such a condition that removal is made difficult.

13. When setting-up on a ferrule-type tube packing, do not exert so much pressure that the tube end is necked or crimped; screw down the ferrules sufficiently, however, to prevent their backing out.

14. Be careful not to damage tube sheets when repairing tube ends or renewing tubes.

15. To prevent corrosion, keep condenser tubes clear of foreign matter.

16. Keep salt water sides of idle condensers dry, especially when ship is in polluted waters.

17. Keep the steam side of secured condensers drained.

18. Keep the salt water sides of condensers in use free from air.

19. Renew temporary taper-plugged tubes at the first opportunity, or close the tube holes with tapered plugs.

20. When boiling out and draining condensers, see that necessary safeguards are provided to protect yourself and others against scalding.

21. Keep salinity indicator systems in constant operation.

AIR EJECTOR SAFETY PRECAUTIONS AND TESTS

The following safety tests and precautions should be remembered for air ejectors:

1. Sentinel and relief valves should be tested at least quarterly.

2. Steam strainers should be inspected at least once a month for the first few months after a new installation has been made, and semiannually thereafter.

3. When starting an air ejector, always open the interstage valves before admitting steam to the nozzles. When securing an air ejector always close tightly the steam supply valves to the nozzles before closing the interstage valves.

4. Before starting an air ejector, always drain the steam supply line, open the drain valves in the inter- and

after-condenser drain lines, and be sure the atmospheric vent line is clear.

5. Should retubing or any other major repairs to an air ejector assembly be necessary, all parts should be hydrostatically tested following reassembly.

AUXILIARY STEAM CONDENSERS

Condensers that serve turbogenerators are generally referred to as AUXILIARY CONDENSERS (fig. 7–7). They operate on the same principle as main condensers. The cooling water, however, is pumped through the condenser at all times, instead of being scoop injected. The circulating water may also make more than one pass, thus classifying the condenser as a multi-pass type. The sea-water chest of the illustrated condenser, you will note, is divided into an inlet chamber and a discharge chamber.

The auxiliary exhaust may go either to the main condenser or the auxiliary condenser. However, in port, the auxiliary exhaust goes only to the auxiliary condenser. When getting under way, the exhaust goes to the auxiliary condenser until vacuum in the main condenser is sufficiently high.

OTHER HEAT EXCHANGERS

Application of the heat exchanger principles are not confined only to shipboard condensers and air ejectors. These principles are also put to work in main lube oil coolers, air coolers, and deaerating feed tanks. In the following sections of this chapter we shall discuss the other kinds of heat exchangers.

MAIN LUBE OIL COOLERS

Main lube oil coolers are usually of the shell and straight tube type and may be of single or multipass construction. In all modern type Navy ships the main lube oil coolers are installed horizontally as illustrated

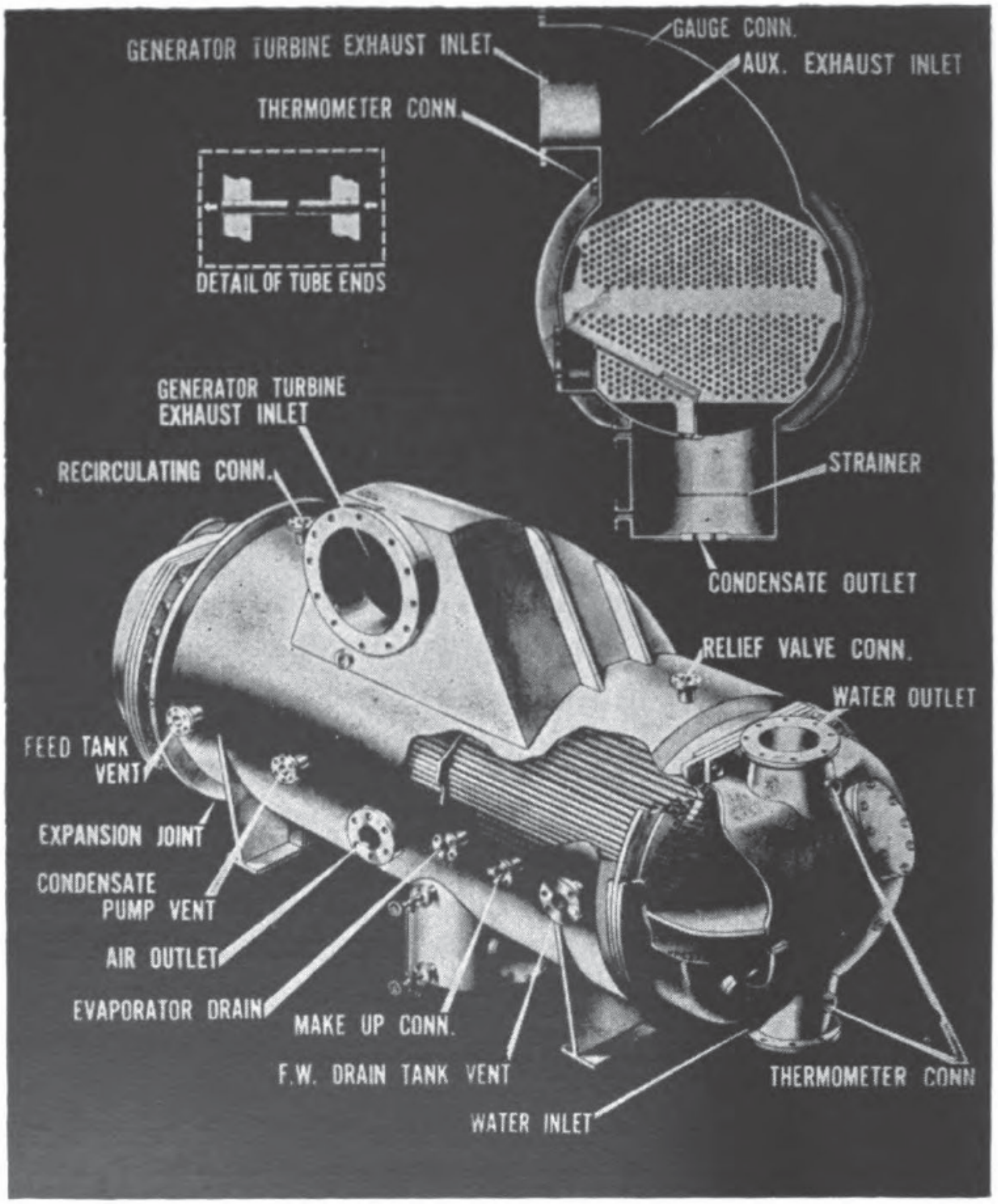
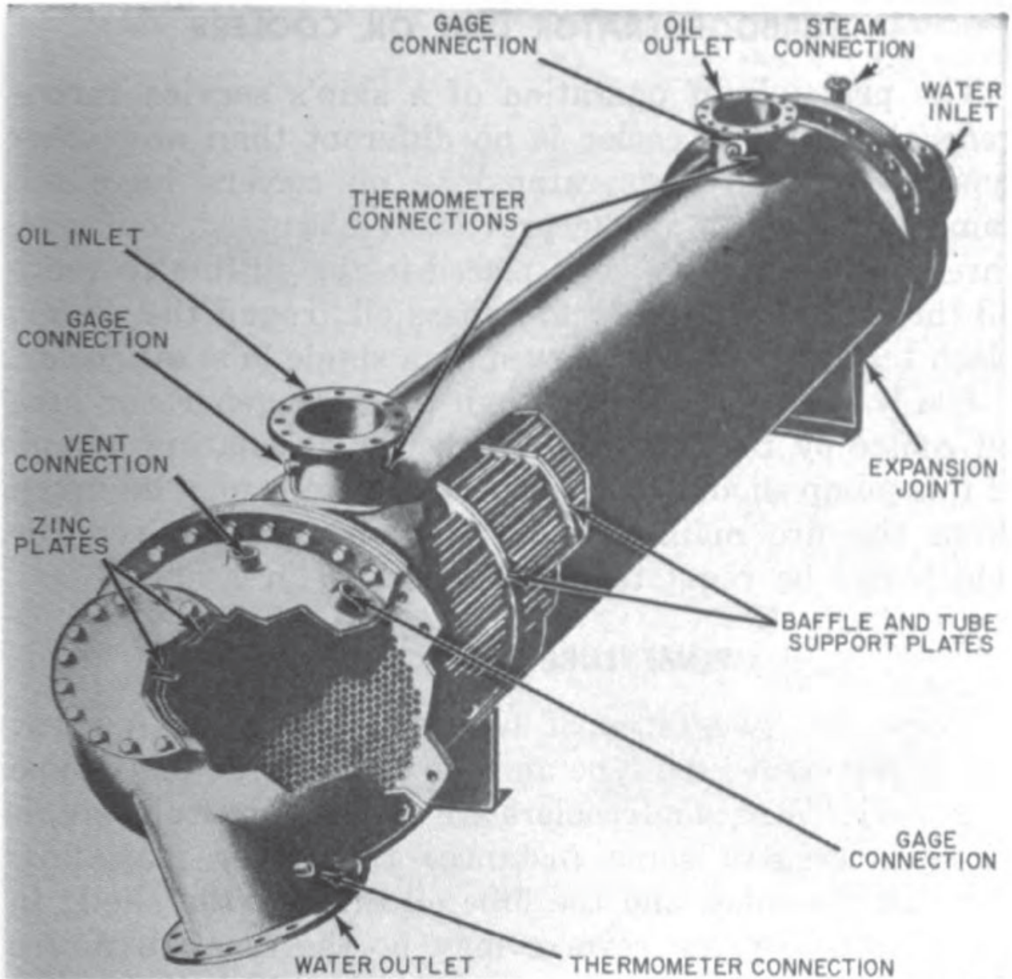


Figure 7–7.—Typical auxiliary steam (turbogenerator) condenser.

in figure 7–8. The size of an oil cooler depends upon the quantity of heat to be removed per unit of time from the lube oil for maintaining proper bearing temperature.

The lube oil cooler consists of a cylindrical shell to which a header has been added at either end. Inside the shell is a bundle of straight copper-nickel tubes through which the cooling water flows from one header to the other. Hot lube oil enters at the top of the shell, opposite



Courtesy of U. S. Naval Institute

Figure 7–8.—Main lube oil cooler.

the water outlet, and flows across the tubes and around the annular jacket. The cooled oil comes out of the top of the cooler adjacent to the water inlet heater. The baffles and tube support plates direct the oil flow. Inside each header a zinc is secured to protect the metal surfaces against galvanic action.

A bypass valve is installed in the oil inlet line to the cooler. The purpose of this bypass is to isolate the cooler in event of a cooler casualty. On more recent ships this bypass has been omitted.

On lube oil cooler's upper surface you will find a steam connection which is usually used for warming up cold lube oil prior to getting under way.

TURBOGENERATOR LUBE OIL COOLERS

The principle of operation of a ship's service turbogenerator lube oil cooler is no different than any other type cooler. Turbogenerator lube oil coolers have the same construction as the previously discussed cooler. A three-way selector valve is placed in the oil line to route oil through the cooler or to bypass oil around the cooler. Each turbogenerator is served by a single lube oil cooler.

Sea water is pumped through the turbogenerator lube oil cooler by the auxiliary condenser circulating pump. If this pump should fail, then cooling water may be taken from the fire main through a cooling water reducer which can be regulated to the desired pressure.

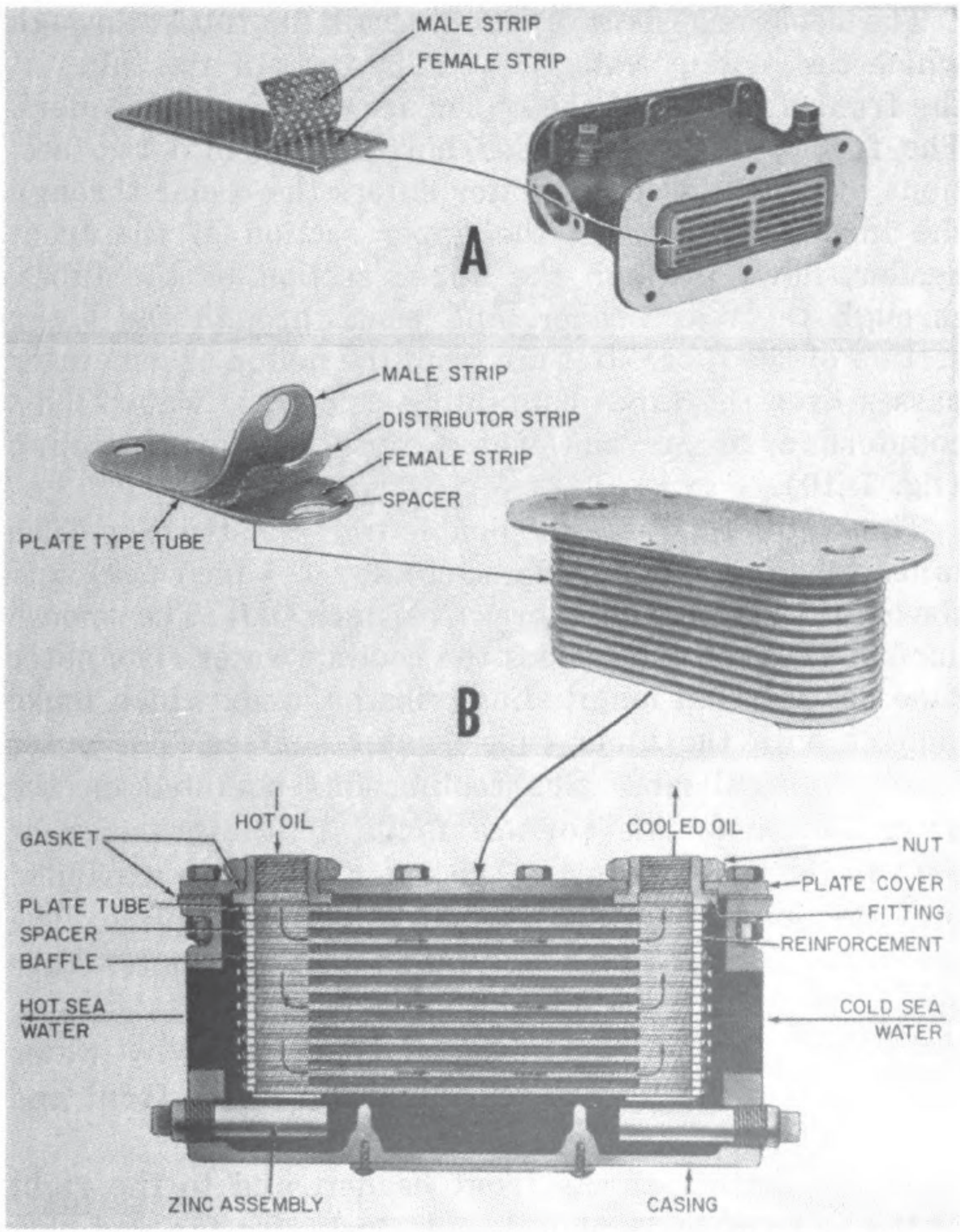
PUMP LUBE OIL COOLERS

There are two types of lube oil coolers for pumps: one is the strut tube type and the other is the plate type (fig. 7–9). These small coolers are usually multitube single pass coolers. In some instances the water may flow through the tubes and the lube oil through the shell; in other instances the reverse may be the case. In figure 7–9A we see a strut type oil cooler in which the water passes through the tubes. In this instance, heat transfer is accelerated by stamped dimples in the strut tube plate. The strut tube plates are assembled so that the convex sides of the dimples touch. Figure 7–9B illustrates a plate type oil cooler for a pump. In this type of cooler the lube oil passes through the tubes. The grid distributor strip accelerates the transfer of heat from the tubes.

The care and maintenance of lube oil coolers is the same as for condensers.

AIR COOLERS

A surface air cooler is installed on shipboard propulsion motors and generators to keep them running cool. The cooler is connected to the air-intake and air-discharge openings of the motor or generator by suitable ducts.



Courtesy of U. S. Naval Institute

Figure 7–9.—Oil coolers for pumps: (A) strut tube type oil cooler; (B) plate type oil cooler.

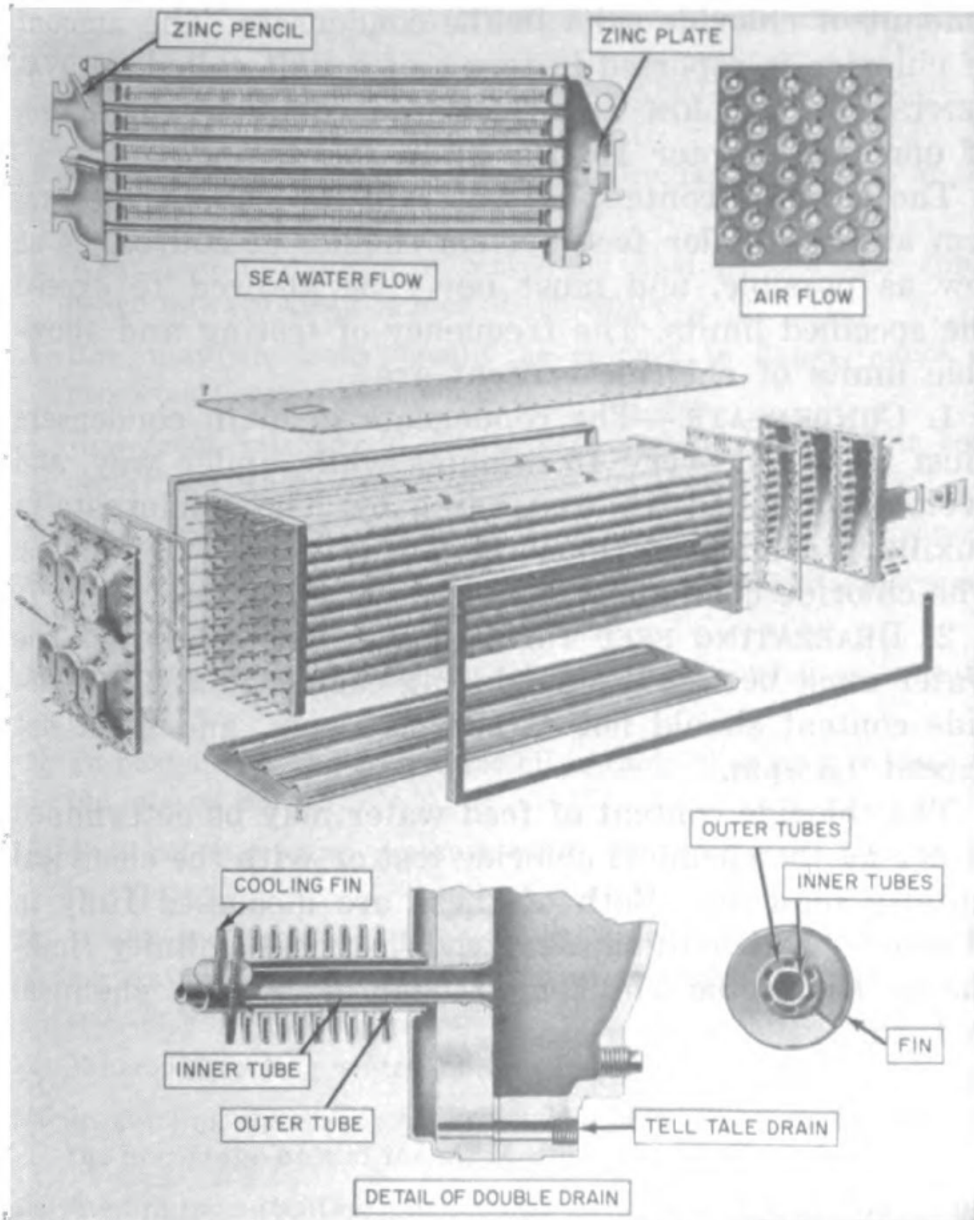
The only characteristic difference between a lube oil cooler and a propulsion motor and generator air cooler is that the latter always has cooling fins on the tubes.

The cooler consists of double-wall fin tubes through which the cooling water flows. The ends of the tubes at the front and rear of the cooler are enclosed by headers. The front header is divided horizontally into two sections by a wall. Cooling water enters the cooler through the inlet connection in the upper section of the front header, flows through the upper section of the tubes, through the rear header, and back through the lower section of the tubes. Hot air from the motor or generator passes over the tubes containing cold inlet water. This counterflow of air and water gives maximum cooling (fig. 7–10).

The water tubes are of double-wall construction. The inner tube is of a copper-nickel alloy (5/8-inch OD) and the outer tube is made of brass (3/4-inch OD). The smooth surfaced inner tube carries the cooling water. The outer tube has internal longitudinal ribs or lands which make contact with the inner tube's outer surface. The outer tube's internal ribs, plus cooling fins mounted on the outer tube's outside surface facilitate the transfer of heat to the cooling water. The outer tubes are expanded into the inner tube sheets and soldered in place. The inner tubes are tightly expanded into the outer tube sheets to make a watertight joint (fig. 7–10).

Failure of an inner tube can be detected by water leaking from the 1/4-inch tell-tale drain in the front and rear header.

At the bottom of the front header, and to the right of the leakage drain plug, is a 1/2-inch pipe tap and plug for draining water from the cooler. At the top of the front and rear header is a 1/2-inch pipe size vent plug. These air-relief plugs should be removed whenever the cooler, after having been drained of water, is to be refilled. The plugs should be removed from the tell-tale



Courtesy of U. S. Naval Institute

Figure 7–10.—Air cooler for a motor or turbogenerator.

drain system so that a leak can be detected from the cooler's tube section.

CONDENSATE CHLORIDE TEST

At regular specified periods, engineroom personnel must test condensate (feed water) for chloride content. The chloride content is used as an indication of the total

amount of chloride salts in the condensate. The amount of chloride is reported in terms of a unit called EQUIVALENTS PER MILLION (epm). For a complete discussion of epm see chapter 10, Distilling Plants.

The chloride content of water in the condensate system and the boiler feed system should, of course, be as low as possible, and must never be allowed to exceed the specified limits. The frequency of testing and allowable limits of chloride content are:

1. CONDENSATE.—The condensate in main condensers must be tested every 15 minutes while under way, and every 30 minutes while standing by. The condensate in auxiliary condensers must be tested every 30 minutes. The chloride content must not exceed 0.1 epm.

2. DEAERATING FEED TANKS (or SURGE TANKS).—The water must be tested once during each watch. The chloride content should not exceed 0.15 epm, and must not exceed 0.5 epm.

The chloride content of feed water may be determined either by the chemical chloride test or with the electrical salinity indicator. Both of these are discussed fully in chapter 10, Distilling Plants. Electrical salinity indicators should be checked frequently by the chemical method.

QUIZ

1. How does a heat exchanger change a vaporized liquid back to a liquid?
2. What is the purpose of the baffles in the injection scoop of the main condenser system?
3. What two purposes are served by having condenser tubes bowed upward about ½ inch at the center?
4. How may air leaks usually be stopped in flange joints or porous castings of a condenser?
5. How frequently should zinc protector plates, installed in condenser sea water chests and lines, be thoroughly scaled?
6. How may the sea water side of condenser tubes be cleaned?
7. At what time should the condensate pump be started when raising vacuum?
8. How is the vacuum broken when a main condenser is being secured?
9. To hasten starting when lube oil is cold, what may be done to the lube oil cooler?
10. To what maximum pressure may condenser sea-water chests be exposed?
11. If the auxiliary circulating pump fails to supply the turbo-generator lube oil cooler with water, where can you obtain cooling water?
12. Where is cooling water obtained for the air ejector?
13. In starting up an air ejector, when should the steam valve to the first-stage unit of the air ejector be opened?
14. Continuing attention must be given to what three things concerning operation of the air ejector after it has been properly started?
15. What may result if insufficient cooling water is provided for an air ejector?
16. What is the first thing to be done when securing an air ejector?
17. What are the three functions of a deaerating feed tank?
18. What pressure is maintained in the deaerating feed tank?

CHAPTER 8

PUMPS

Pumps are so widely used, for such varied services, that the number of different designs is almost overwhelming. As a general rule, however, you can remember that all pumps are designed to move fluid substances from one point to another by pulling, pushing, or throwing, or by some combination of these three methods.

You should remember, also, that no matter how complicated a pump looks it must have a POWER END and a FLUID END. The power end may be a steam turbine, a reciprocating steam engine, a steam jet, or an electric motor. In steam-driven pumps, the power end is often called the STEAM END. The fluid end is generally called the PUMP END; however, it may be called the LIQUID END, the WATER END, the OIL END, the GAS END, etc., to indicate the nature of the fluid substance being pumped.

On board ship, pumps are used for a number of essential services. Pumps feed water to the boilers, draw condensate from the condensers, supply sea water to the firemain, circulate cooling water for coolers and condensers, empty the bilges, transfer fuel oil, discharge fuel oil to the burners, and serve many other purposes. The operation of the ship's propulsion plant and of almost all auxiliary machinery depends upon the proper operation of pumps. Pump failure may cause failure of an entire power plant.

As a Machinist's Mate, you will be required to know

about the operation and maintenance of the engineroom pumps which are discussed in this chapter. Before studying this chapter, however, you should have at your command a general knowledge of the basic operating principles of various types of pumps. You may find it helpful to review this subject in *Fireman,* NavPers 10520–A. In addition, you will find it necessary to refer to chapter 3, Main and Auxiliary Turbines, since many of the pumps to be described here are driven by steam turbines. In this chapter we will deal primarily with the three major classifications of pumps—reciprocating, rotary, and centrifugal pumps—because these are the types you will most frequently find in the engineroom. A section will be devoted to eductors, a type of jet pump. For information on other types of pumps, you should consult chapter 47 of the *Bureau of Ships Manual* and appropriate manufacturers' instruction books.

RECIPROCATING PUMPS

The reciprocating pump moves water or other liquid by means of a plunger which reciprocates—that is, goes back and forth or up and down—within a cylinder. Reciprocating pumps are usually classified as:

1. Direct- or indirect-acting.
2. Simplex (single) or duplex (double).
3. Single-acting or double-acting.
4. High-pressure or low-pressure.
5. Vertical or horizontal.

The reciprocating pump shown in figure 8–1 is a direct-acting, simplex, double-acting, high-pressure, vertical pump. Now let's see what all these terms mean, with reference to the pump shown in the illustration.

The pump is DIRECT-ACTING because the pump rod is a DIRECT extension of the piston rod; and, therefore, the piston in the power end is DIRECTLY connected to the plunger in the liquid end. Most reciprocating pumps used in the Navy are direct-acting. An INDIRECT-ACTING pump

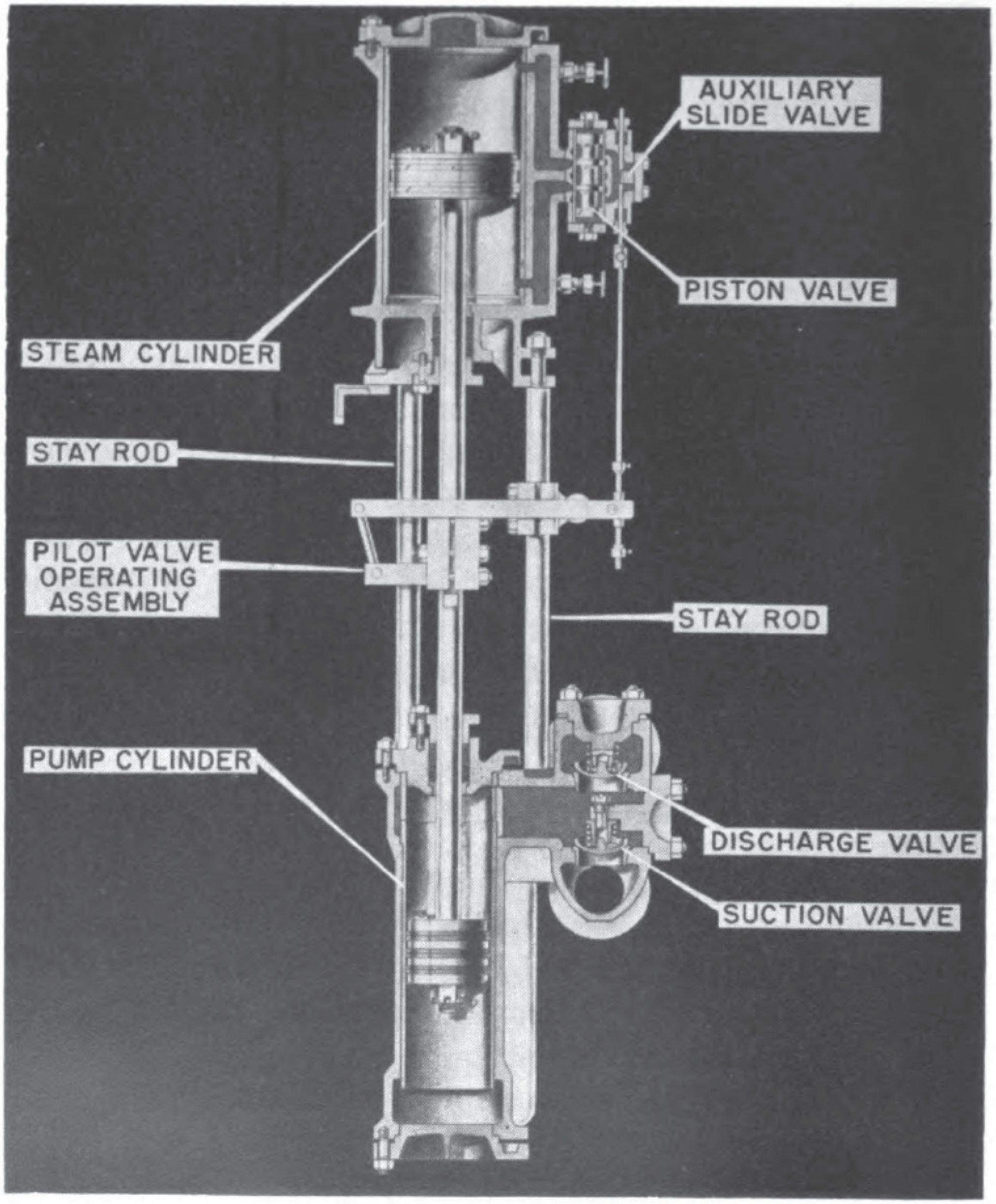


Figure 8–1.—Reciprocating pump.

may be driven by means of a beam or linkage which is connected to and motivated by the steam piston rod in a separate reciprocating engine; or it may be driven by a crank-and-connecting rod mechanism which is operated by a steam turbine or an electric motor. An indirect-acting pump might appear to have only one end—that is, the pump end. However, don't forget that this pump, like all others, must have a power end as well. The

separate engine, turbine, or motor which drives the pump is the actual power end of the pump.

The pump shown in figure 8–1 is called a SINGLE or SIMPLEX pump because it has only one liquid cylinder. Simplex pumps may be either direct-acting or indirect-acting. A DOUBLE OR DUPLEX pump is an assembly of two single pumps, placed side by side on the same foundation; the two steam cylinders are cast in a single block, and the two liquid cylinders are cast in another block. Duplex reciprocating pumps are seldom found in modern combatant vessels, but were commonly used in older ships.

In a SINGLE-ACTING pump, the liquid is drawn into the liquid cylinder on the first or SUCTION STROKE and is forced out of the cylinder on the return or DISCHARGE STROKE. In a DOUBLE-ACTING pump, each stroke serves both to draw in liquid and to discharge liquid. As one end of the cylinder is filled, the other end is emptied; on the return stroke, the end which was just emptied is filled and the end which was just filled is emptied. The pump shown in figure 8–1 is double-acting, as are most of the reciprocating pumps used in the Navy.

The pump shown in figure 8–1 is designed to operate with a discharge pressure which is higher than the pressure of the steam operating the piston in the steam cylinder. In other words, this is a HIGH-PRESSURE pump. In a high-pressure pump, the steam piston is larger in diameter than the plunger in the liquid cylinder. Since the area of the steam piston is greater than the area of the plunger in the liquid cylinder, the total force exerted by the steam against the steam piston is concentrated on the smaller working area of the plunger in the liquid cylinder; and, therefore, the pressure per square inch is greater in the liquid cylinder than in the steam cylinder. A high-pressure pump discharges a comparatively small volume of liquid against a high pressure. A LOW-PRESSURE pump, on the other hand, has a comparatively low discharge pressure but a larger volume of discharge.

In a low-pressure pump, of course, the steam piston is smaller than the plunger in the liquid cylinder.

The standard way of designating the size of a reciprocating pump is by giving three dimensions, in the following order: (1) the diameter of the steam piston; (2) the diameter of the pump plunger; and (3) the length of the stroke. For example, a 12″ x 11″ x 18″ reciprocating pump has a steam piston which is 12 inches in diameter, a pump plunger which is 11 inches in diameter, and a stroke of 18 inches. As you can see, the designation enables you to tell immediately whether the pump is a high pressure or low pressure pump.

Finally, the pump shown in figure 8–1 is classified as VERTICAL because the steam piston and the pump plunger move up and down. Most reciprocating pumps in naval use are vertical; but you may occasionally encounter a HORIZONTAL pump, in which the piston moves back and forth rather than up and down.

The following discussion of reciprocating pumps is generally concerned with direct-acting, simplex, double-acting, vertical pumps, since most reciprocating pumps used in the Navy are of this type.

Construction of Reciprocating Pumps

The power end of a reciprocating pump consists of a bored cylinder in which the steam piston reciprocates. The steam cylinder is fitted with heads at each end; one head has an opening to accommodate the piston rod. Steam inlet and exhaust ports connect each end of the steam cylinder with the steam chest. Drain valves are installed in the steam cylinder, so that water resulting from condensation may be drained off.

Some reciprocating pumps have cushioning valves at each end of the steam cylinder. These valves can be adjusted to trap a certain amount of steam at the end of the cylinder; thus, when the piston reaches the end of its stroke, it is cushioned by the steam and prevented from hitting the end of the cylinder. When the pump is

operating at high speeds, the cushioning valves should be nearly closed so that a considerable amount of steam will be trapped at each end of the cylinder; at low speeds, the cushioning valves should be almost open. (The steam cylinder shown in figure 8–2 does not have cushioning valves.)

Automatic timing of the admission and release of steam to and from each end of the steam cylinder is accomplished by various types of valve arrangements. Figure 8–2 shows the piston-type valve gear commonly used for this purpose; it consists of a main piston-type slide valve and a pilot slide valve. Since the rod from the pilot valve is connected to the pump rod by a valve-

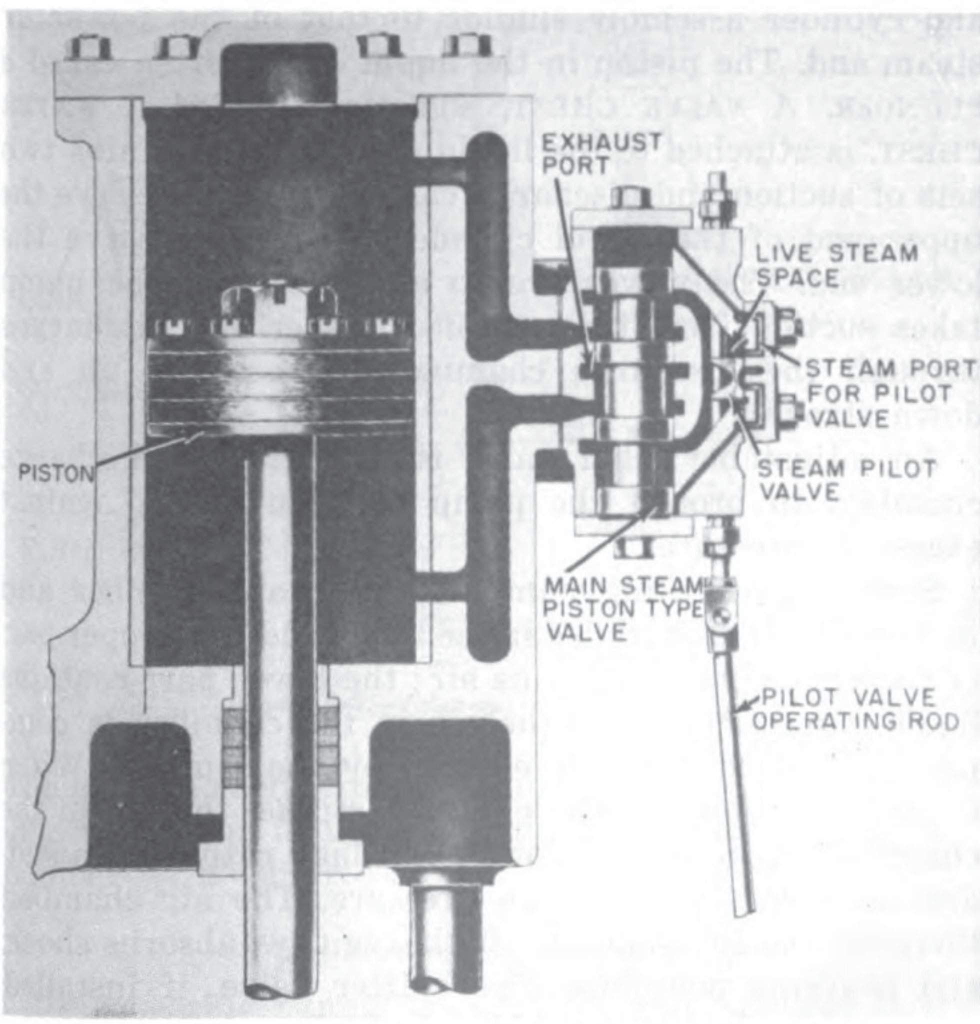


Figure 8–2.—Piston-type valve gear for steam end of reciprocating pump.

operating assembly, the position of the pilot valve is controlled by the position of the piston in the steam cylinder. The pilot valve furnishes actuating steam to the main piston-type valve, which, in turn, admits steam to the top or the bottom of the steam cylinder at the proper time.

The valve-operating assembly which connects the pilot valve operating rod and the pump rod is shown in figure 8–3. As the crosshead arm (sometimes called the rocker arm) is moved up and down by the movement of the pump rod, the moving tappet slides up and down on the pilot valve rod. The tappet collars are adjusted so that the pump will make the full designed stroke.

The liquid end of a reciprocating pump has a piston and cylinder assembly similar to that of the power or steam end. The piston in the liquid end is often called a PLUNGER. A VALVE CHEST, sometimes called a WATER CHEST, is attached to the liquid cylinder; it contains two sets of suction and discharge valves, one set to serve the upper end of the liquid cylinder and one to serve the lower end. The valves are so arranged that the pump takes suction from the suction chamber and discharges through the discharge chamber on both the up and down strokes.

An adjustable relief valve is fitted to the discharge chamber, to protect the pump and the piping against excessive pressure.

Some reciprocating pumps have an air chamber and a SNIFTER VALVE installed in the liquid end. The upper part of the air chamber contains air; the lower part contains liquid. On each stroke, the air in the chamber is compressed by the pressure exerted by the plunger. When the plunger stops at the end of a stroke, the air in the chamber expands and allows a gradual, rather than sudden, drop in the discharge pressure. The air chamber, therefore, smooths out the discharge flow, absorbs shock, and prevents pounding. The snifter valve, if installed, allows a small quantity of air to be drawn in and com-

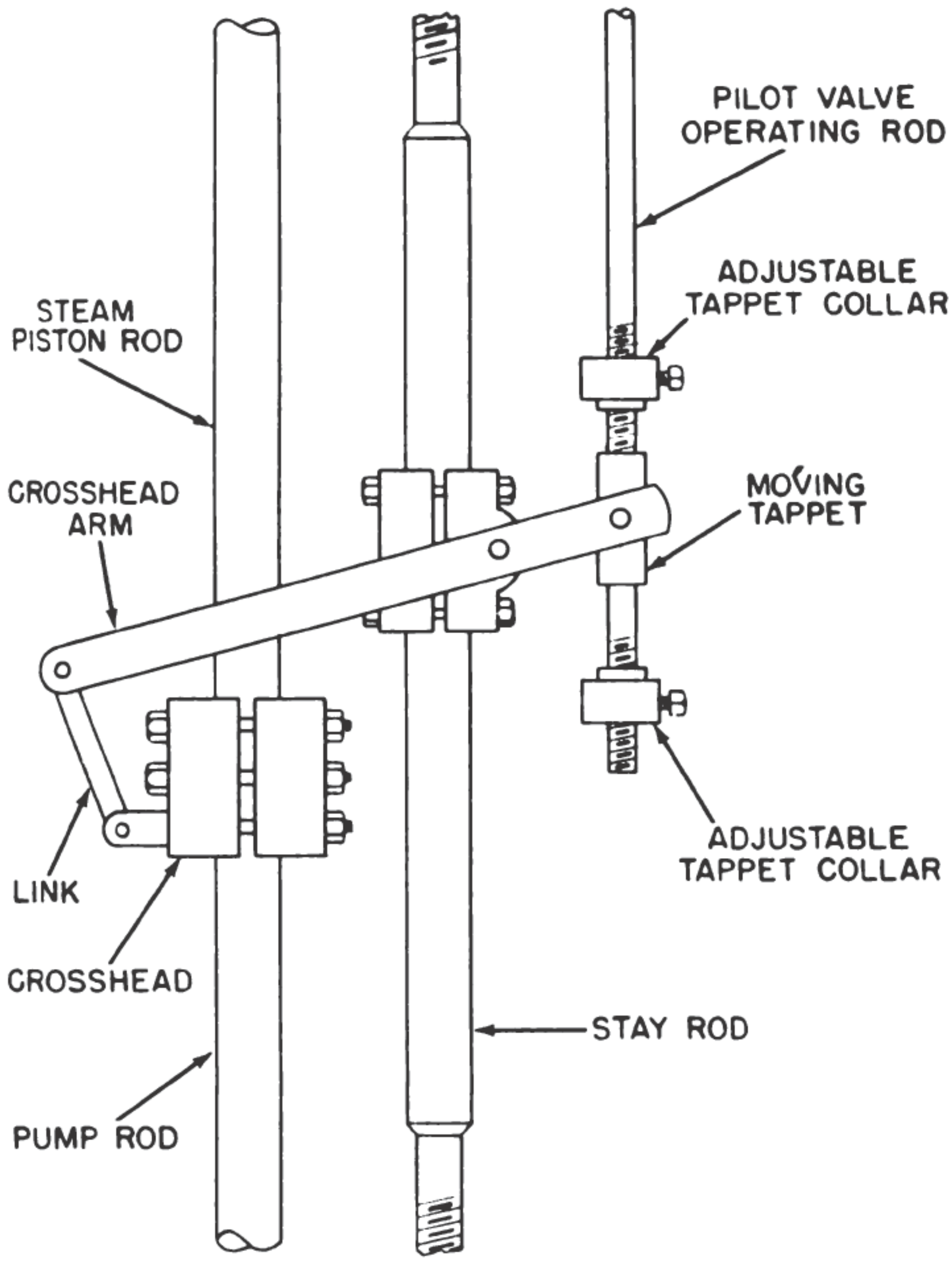


Figure 8–3.—Valve-operating assembly.

pressed with each stroke. If no snifter valve is installed, some provision is usually made for charging the air chamber with compressed air.

Engineroom Applications

Reciprocating pumps are used for two purposes in the main machinery spaces: (1) as fire and bilge pumps; and

(2) as emergency or auxiliary feed pumps. Reciprocating pumps are very good for emergency use because they are relatively simple, reliable, and easy to start and operate under cold conditions.

The FIRE AND BILGE PUMP is sometimes called the STANDBY FIRE PUMP. In an emergency, it is used as a fire-and-flushing pump. Operation of the fire and bilge pump is similar to the general operation of reciprocating pumps described in previous pages.

Procedures for the operation, maintenance, and repair of the fire and bilge pump are, in general, the same as for any other reciprocating pump. With the fire and bilge pump, however, special precautions must be taken to see that the suction strainers are kept clean. Clogged suction strainers and the presence of foreign matter in the water chest suction and discharge valves are the most frequent causes of trouble in the liquid end of the fire and bilge pump.

The EMERGENCY or AUXILIARY FEED PUMP is a direct-acting, simplex, double-acting, high-pressure, vertical pump of the type shown in figure 8–1. The pump is operated from the auxiliary steam line. It is used for filling idle boilers, for transferring reserve feed water, for applying pressure to boilers undergoing hydrostatic test, and in some cases for regular boiler feed service for in-port (auxiliary) steaming. This pump does not have sufficient capacity for high firing rates, and its use is therefore limited to emergency or auxiliary service.

Operation of Reciprocating Pumps

The general procedure for starting a reciprocating pump is as follows:

1. Check that the steam cylinder and chest drain valves are open. (They should have been opened when the pump was shut down.)
2. Oil the pins of the steam valve operating gear; and set up on any grease cups which may be fitted.

(Some modern reciprocating pumps do not have grease cups.)

3. Open the liquid end suction and discharge valves.
4. Open the exhaust and steam line root valves (if installed).
5. Open the steam exhaust valve (cutout valve) at the pump.
6. Crack open the steam throttle valve and admit steam SLOWLY so that the steam cylinder will warm up gradually.
7. Close the steam cylinder drains after the pump has made a few strokes. Do not close these drains until the steam cylinder is clear of water.
8. Open the throttle valve slowly to bring the pump up to the desired operating speed or discharge pressure.
9. Follow any additional instructions indicated by experience with a particular design of pump or laid down by the engineering officer.

In general, the steps to be followed in stopping and securing a reciprocating pump are:

1. Close the steam throttle valve.
2. Open the steam cylinder drains.
3. Close the steam exhaust valve at the pump.
4. Close the liquid end suction and discharge valves.
5. Close the steam and exhaust root valves.

Sometimes you will find that the pump won't kick over when you line it up and crack open the throttle valve. You may open the throttle a little wider, but still nothing happens. You go through the whole starting procedure again, to make sure that everything has been done correctly—but still the pump will not run. At this point, proceed as follows:

1. Secure the pump.
2. Examine the discharge line and the exhaust line. The trouble may be a closed valve, or a valve in which the disk has become detached from the stem.

3. Check the rod packing glands at the steam end and at the water end; if someone has set up on them too tightly, the pump may be locked so that it cannot move.
4. If the trouble cannot be located by any of the above measures, report the fact to the proper authority.

From time to time you are likely to have some operating troubles with reciprocating pumps. Some of the most common causes of trouble, together with their symptoms and remedies, are described here.

Lack of proper suction will cause jerky or irregular operation of the pump, or it may cause the pump to race without any appreciable increase in discharge pressure. Loss of suction may be caused by a number of different conditions, including:

1. Obstructions in the suction line.
2. Loss of suction head, which causes the pump to become vapor-bound.
3. Air in the system, which causes the pump to become air-bound.

Obstructions in the suction line frequently cause trouble in the case of fire and bilge pumps. Be sure that the suction line is clear and that all stop or check valves in the line are open. Clean the suction line strainer and the bilge strainer.

A pump can lose suction by becoming air-bound—that is, having air trapped in the system. The remedy for this condition is to open the aircocks and vents on the liquid end valve chest; leave them open until water flows out.

Insufficient prime often causes loss of suction in pumps which have a considerable suction lift. The fire and bilge pump can usually be primed from the sea by opening the sea suction valve for a short time.

Worn packing on the plunger or damaged suction or discharge valves in the liquid end may cause the pump to race without an appreciable increase in discharge pressure. It is hard to distinguish this kind of trouble from the troubles caused by loss of suction, since the

general symptons are very similar. However, if you suspect that the plunger packing is worn or that the liquid end valves are damaged, you should stop the pump as soon as possible and locate and correct the trouble.

Groaning in the steam end of the pump may indicate that the packing is too tight, that the piston or a piston ring is broken, that rust has formed in the cylinder, or that the steam cylinder is out of alinement. The pump should be secured so that the difficulty may be found and corrected.

Groaning in the liquid end of the pump is generally due to excessively tight packing or a broken or damaged follower plate or other broken parts. Stop the pump and investigate.

Knocking in the steam end of the pump may be caused by too long a stroke, by water in the steam cylinder, by loose pistons or piston rings, or by some difficulty in the piston-type valve gear. The pump should be stopped at once so that the trouble may be found and corrected.

Proper adjustment of the length of stroke is extremely important. If the stroke is too long, the steam piston will hit against the cylinder heads and make a heavy, metallic knocking sound. When the stroke is too short, the pilot valve may block the ports sufficiently to interfere with the admission of steam into the main valve; and this may cause the pump to stop. In addition, a short stroke causes shoulders to be worn in the cylinder; and when the stroke is lengthened, these shoulders may cause the piston rings to break. Improper length of stroke, whether too short or too long, may cause great damage to the pump. To adjust the pump stroke, throttle down the pump, and adjust the stroke as necessary.

Maintenance and Repair

Reciprocating pumps require a certain amount of routine maintenance and, upon occasion, some repair work. Some of the most important points of maintenance and repair are mentioned here. For further information

you should consult chapter 47 of the *Bureau of Ships Manual,* and the applicable manufacturers' instruction books.

All moving parts of the valve-operating assembly should be kept well oiled. However, you must NOT attempt to lubricate the internal parts of the steam end or of the liquid end of the pump. A slight gland leak-off is sufficient to lubricate the pump rod. Do not use oil on the pump rod.

Piston rod packing should be renewed whenever it becomes worn or dried out. A little routine maintenance here can save you a good deal of work, since it is much easier to renew packing than it is to replace rods.

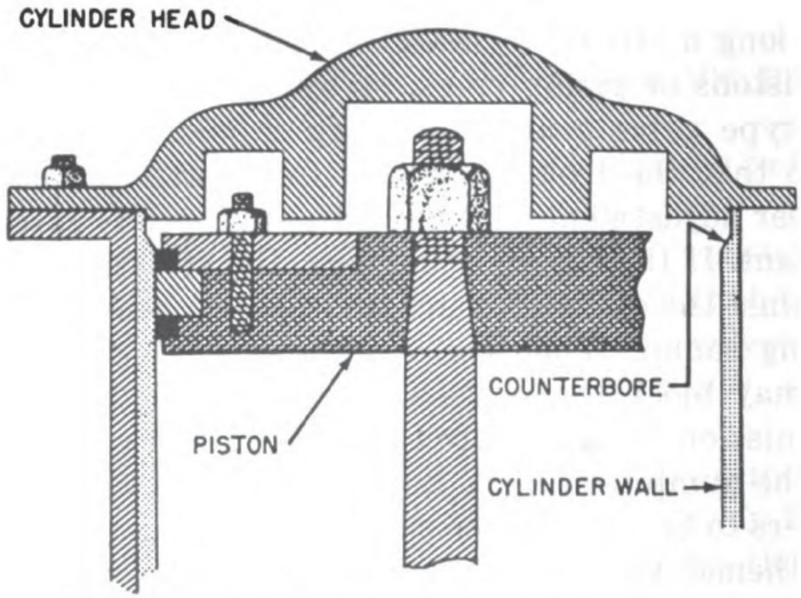


Figure 8–4.—Piston at upper end of stroke.

Stroke adjustment is very important. Be sure that the pump is making a full stroke. The piston should travel a little beyond the top and bottom counterbore. The position of the piston in relation to the top counterbore is shown in figure 8–4.

A stroke indicator is usually provided on reciprocating pumps, as an aid in checking the length of stroke. The

indicator consists of a pointer secured to the piston rod crosshead, and two marks on one of the cylinder tie rods. The upper mark should line up with the pointer on the crosshead when the piston is at the upper end of the stroke; the lower mark should line up with the pointer when the piston is at the lower end of the stroke.

Length of stroke is adjusted by changing the setting of the tappet collars on the pilot valve operating rod. (See figure 8–3.) To shorten the stroke, the tappet collars are moved closer together; to lengthen the stroke, they are moved farther apart. The tappet collars should not be moved unless absolutely necessary. If frequent adjustment of the collars appears to be required, something else is wrong with the pump.

Tests

The following tests should be conducted on reciprocating pumps:

1. Jack over all idle pumps by hand DAILY.
2. Move all pumps by steam or power WEEKLY.
3. Inspect liquid end valves, valve stems, and springs; inspect steam valve gear for wear; and check setting of relief valves QUARTERLY.

Safety Precautions

The following safety precautions concerning reciprocating pumps have been specified by the Bureau of Ships:

1. Never attempt to jack over a pump while the steam valve to the pump is open.
2. Before opening a steam cylinder or a steam chest, be sure that all drains are open and that the steam and exhaust root valves are wired closed.
3. Before opening the water cylinder or the valve chest of a pump handling water at a temperature in excess of 120° F, be sure that the suction and discharge valves are wired closed, and that the cylinder and the valve chest are drained.

4. Always open the steam cylinder drain valves and the steam chest drain valves when the pump is shut down, and leave them open until the pump is again in operation and has been cleared of condensate.

VARIABLE STROKE PUMPS

Variable stroke pumps are used in shipboard hydraulic transmission systems. As an MM3, you will be responsible for maintaining and making minor repairs to hydraulic and related equipment outside your ship's engineering spaces.

Although variable stroke pumps are often classified as rotary pumps, they are actually reciprocating pumps. A rotary motion is imparted to the pump by a constant-speed electric motor, but the actual pumping is performed by a set of pistons reciprocating inside a set of cylinders. The means by which the rotary motion is translated into reciprocating motion is described and illustrated in *Fireman*, NavPers 10520–A.

There are two general types of variable stroke pumps in common use: the axial-piston type and the radial-piston type. In the axial-piston type, the pistons are arranged parallel to each other and to the pump shaft; in the radial-piston type, the pistons are arranged radially from the shaft.

The VARIABLE STROKE AXIAL-PISTON PUMP, shown in figure 8–5, usually has either seven or nine single-acting pistons which are evenly spaced around a cylinder barrel. (Note that the term CYLINDER BARREL, as used in this connection, actually refers to a cylinder BLOCK which holds all the cylinders.) The piston rods make a ball-and-socket connection with a socket ring. The socket ring rides on a thrust bearing carried by a casting called the TILTING BOX or TILTING BLOCK.

When the tilting box is at a right angle to the shaft, and the pump is rotating, the pistons do not reciprocate; therefore, no pumping takes place. When the box is tilted

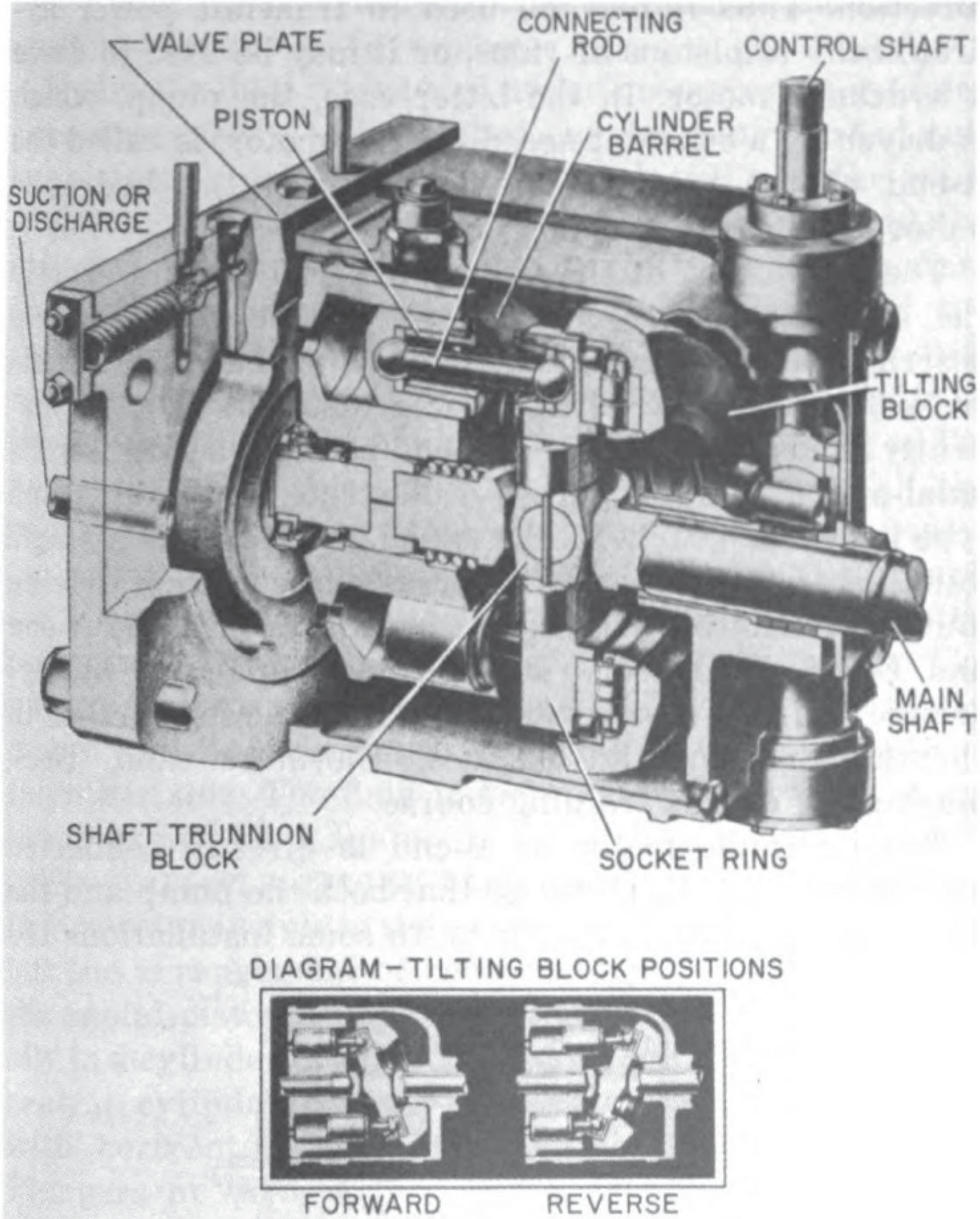


Figure 8–5.—Variable stroke axial-piston pump.

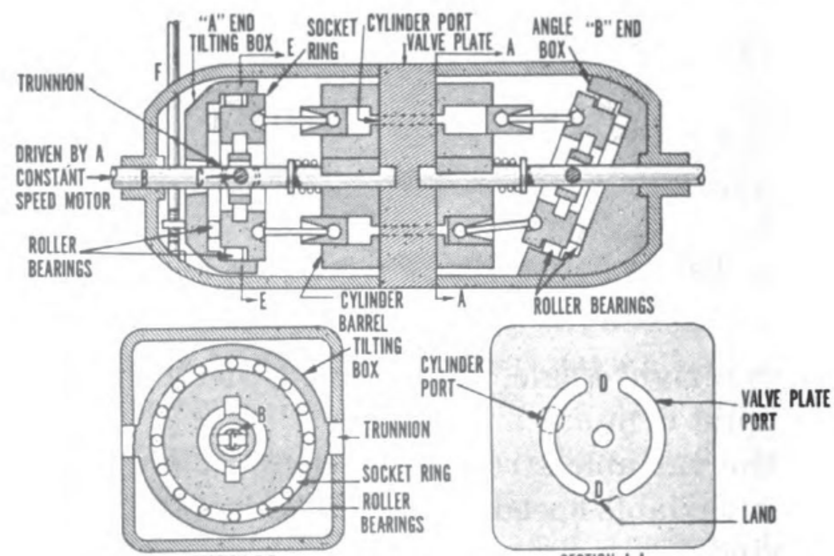
away from a right angle, however, the pistons reciprocate and the liquid is pumped.

When the variable stroke axial-piston pump is used as a part of a variable speed gear such as in electrohydraulic anchor windlasses, cranes and winches, and the power transmitting unit in electrohydraulic steering engines, the tilting box is so arranged that it may be tilted in either

direction. Thus it may be used to transmit power hydraulically to pistons or rams, or it may be used to drive a hydraulic motor. In the latter case, the pump, which is driven by a constant speed electric motor, is called the A-end of the variable speed gear and the hydraulic motor is called the B-end.

The B-end unit of the hydraulic speed gear is exactly the same as the A-end of the variable stroke pump described above, except that it does not have a variable stroke feature. The tilting box is installed at a permanently fixed angle. Thus, the B-end becomes a fixed stroke axial-piston pump. Figure 8–6 illustrates an axial piston type hydraulic gear with the A-end and B-end as a single unit; it is used in turrets for train and elevation driving units. For electrohydraulic winches and cranes, the A-end and B-end are in separate housings connected by hydraulic piping. These latter units are discussed further in chapter 13, Steering Engines, Elevators, and Deck Machinery, of this training course.

The hydraulic motor or B-end is directly connected hydraulically to the pump, so that both the pump and the motor use the same valve plate. In some installations the



Courtesy of U. S. Naval Institute

Figure 8–6.—Axial-piston type hydraulic speed gear.

motor is set up at a distance from the pump, and the two units are connected by piping.

Hydraulic fluid introduced under pressure to a cylinder causes the piston to be pushed out. In being pushed out, the piston, through its connecting rod, will seek the point of greatest distance between the cylinder barrel and the socket ring. The resultant pressure of the piston against the socket ring will cause the cylinder barrel and the socket ring to rotate. This action occurs during the half revolution while the piston is passing the intake port of the motor, which is connected to the pressure port of the pump. After the piston of the motor has taken all the hydraulic fluid it can from the pump, the piston passes the valve plate land and starts to discharge oil through the outlet ports of the motor to the suction inlet of the pump, and thence to suction pistons of the pump. The pump is constantly putting pressure on one side of the motor while it is constantly receiving hydraulic fluid from the other side. The fluid is merely circulated from pump to motor and back again.

The VARIABLE STROKE RADIAL-PISTON PUMP is similar in general principle to the axial-piston type just described, but the arrangement of component parts is different. In the radial-piston pump, the cylinders are arranged radially in a cylinder body which rotates around a nonrotating central cylindrical valve. Each cylinder communicates with horizontal ports in the central cylindrical valve. Plungers or pistons, which extend outward from each cylinder, are pinned at their outer ends to slippers which slide around the inside of a rotating floating ring or housing.

The floating ring is so constructed that it can be shifted off center from the pump shaft. When it is centered, or in the neutral position, the pistons do not reciprocate and the pump does not function, even though the electric motor is still causing the pump to rotate. If the floating ring is forced off center to one side, the pistons reciprocate and the pump operates. If the floating ring is forced

off center to the other side of the pump shaft, the pump also operates but the direction of the flow is reversed. Thus it can be seen that the direction of flow and the amount of flow are both determined by the position of the cylinder body relative to the position of the floating ring.

When used for fuel oil service, variable stroke pumps are designed to be nonreversing. They operate at constant speed, with a constant discharge pressure, but with variable capacity. The shipboard application of reversible type variable stroke pumps is found in such hydraulic transmission gear as steering mechanisms. For a complete explanation of this gear, refer to chapter 13, Steering Engines, Elevators, and Deck Machinery, of this training course.

ROTARY PUMPS

All rotary pumps work by means of rotating parts which trap the liquid at the suction side and force it through the discharge outlet. Gears, screws, lobes, vanes, and cam-and-plunger arrangements are commonly used as rotating elements in rotary pumps. Rotary pumps, like reciprocating pumps, operate on the positive-displacement principle—that is, each rotation or each stroke delivers a definite quantity of liquid.

Rotary pumps are particularly useful for pumping oil and other heavy, viscous liquids. In the engineroom this type of pump is used for lube oil service. In some ships a rotary fuel oil transfer pump is located in the engineroom. Rotary pumps are also used for nonviscous liquids, such as water or gasoline, where the pumping problem involves a high suction lift. The power end of a rotary pump is usually an electric motor or a steam-driven turbine.

Rotary pumps are designed with very small clearances between rotating parts, and between rotating parts and stationary parts, in order to minimize slippage from the discharge side back to the suction side. Rotary pumps are

designed to operate at relatively low speeds in order to maintain these clearances; operation at higher speeds would cause erosion and excessive wear, which would result in increased clearances.

Types of Rotary Pumps

Classification of rotary pumps is generally made according to the type of rotating element. In the following paragraphs we will discuss briefly the main features of gear pumps and screw pumps.

The SIMPLE GEAR PUMP has two spur gears which mesh together and revolve in opposite directions. One is the DRIVING GEAR, and the other is the DRIVEN GEAR. Clearances between the gear teeth (outside diameter of gear) and the casing and between the end face and the casing are only a few thousandths of an inch. The action of the unmeshing gears draws the liquid into the suction side of the pump. The liquid is then trapped in the pockets formed by the gear teeth and the casing, so that it must follow along with the teeth. On the discharge side, the liquid is forced out by the meshing of the gears.

The HERRINGBONE GEAR PUMP is a modification of the simple gear pump (fig. 8–7). In the herringbone gear type, one discharge phase begins before the previous discharge phase is entirely complete; and this overlapping tends to give a steadier discharge pressure than is found in the simple gear pump. Power-driven pumps of this type are sometimes used for low-pressure fuel oil service, lubricating oil service, and Diesel oil service.

The HELICAL GEAR PUMP is still another modification of the simple gear pump. Because of the helical gear design, the overlapping of successive discharges from spaces between the teeth is even greater than it is in the herringbone gear pump; and the discharge flow is, accordingly, even smoother. Since the discharge flow is smooth in the helical gear pump, the gears can be designed with a small number of large teeth—thus allowing increased capacity without sacrificing smoothness of flow.

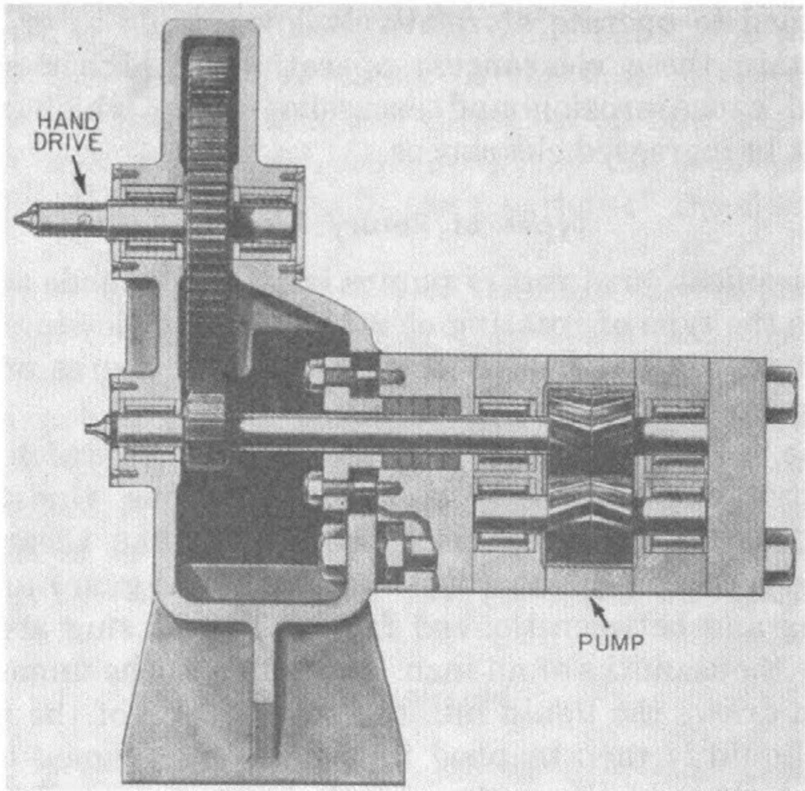


Figure 8-7.—Herringbone gear pump.

The pumping gears in this type of pump are driven by a set of timing and driving gears, which also function to maintain the required close clearances while preventing actual metallic contact between the pumping gears. (As a matter of fact, metallic contact between the teeth of the pumping gears would provide a tighter seal against slippage; but it would cause rapid wear of the teeth because foreign matter in the pumped liquid wou'd be present on the contact surfaces.)

Roller bearings at both ends of the gear shafts maintain proper alinement, and so minimize the friction loss in the transmission of power. Stuffing boxes are used to prevent leakage at the shafts. The helical gear pump is used to pump nonviscous liquids and light oils at high speed. It can also be used to pump heavy, viscous materials at lower speed.

The LOBE-TYPE PUMP is still another variation of the

simple gear pump. The lobes are considerably larger than gear teeth, but there are only two or three lobes on each rotor. The rotors are driven by external spur gears on the rotor shafts. Some lobe pumps are made with replaceable inserts (gibs) at the extremities of the lobes. These inserts take up the wear which would otherwise be sustained by the ends of the lobes; and, in addition, they maintain a tight seal between the lobe ends and the casing. The inserts are usually seated on a spring, and are thus able to automatically compensate for considerable wear of both the gibs and the casing. Replaceable cover plates (liner plates) are fitted at each end of the casing, where the lobe faces cause heavy wear.

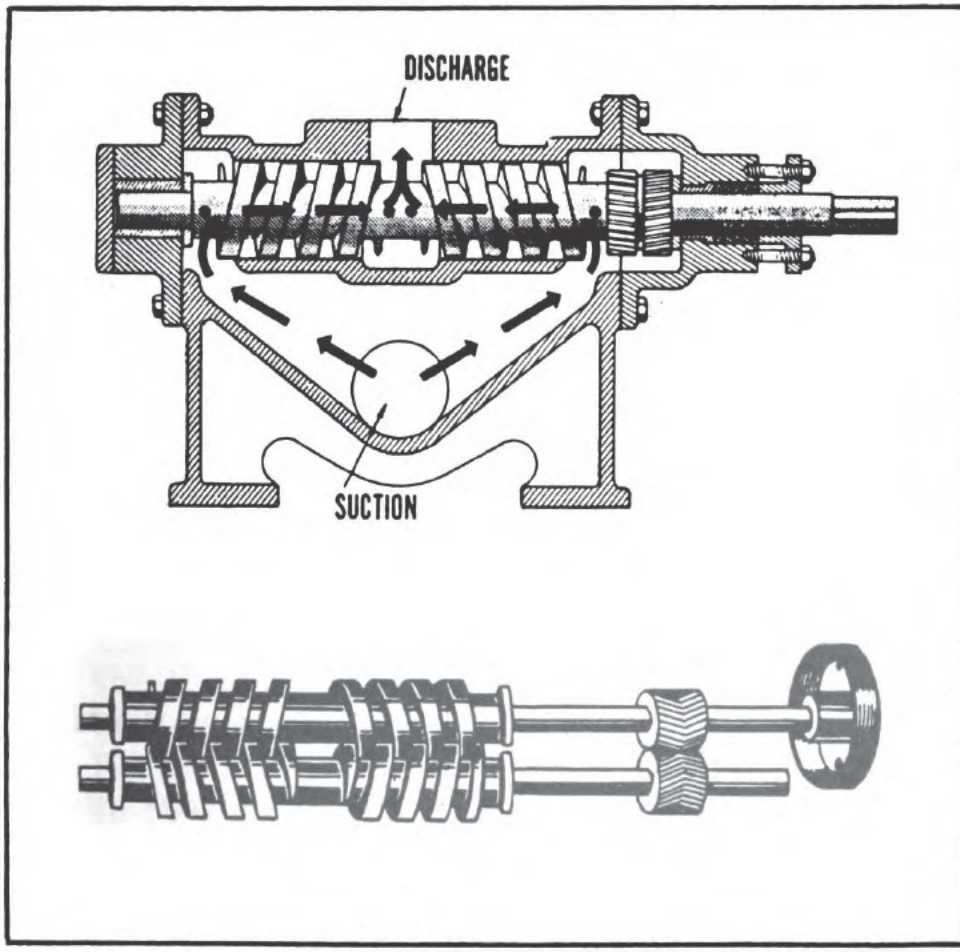


Figure 8–8.—Positive displacement, double-screw low-pitch pump.

There are several types of SCREW PUMPS. The main points of difference between the various types are the number of intermeshing screws and the pitch of the screws. Figure 8–8 shows a type of screw pump which is used on board ship for main lube oil service. An example of a positive displacement, triple-screw high-pitch rotary pump is illustrated in figure 6–3.

Operation of Rotary Pumps

The general procedure for starting and operating a rotary pump is as follows:

1. Check the lubricating oil level in the pump end reservoir and in the turbine end reservoir, and add oil if necessary. Rotate the handle of the lube oil filter when starting the pump, and at least once during each watch. If the rotary pump is lubricated by a separate lubricating pump, be sure to open and adjust all oil delivery and return valves.
2. Lubricate the linkage and slides on the speed-limiting governor. If a gravity-feed oil cup is provided for the end bearing of the governor spindle, lift the snap tip needle valve to a vertical position, and check to be sure that oil is being fed at the proper rate—about 5 to 10 drops per minute, or as recommended by the manufacturer's instruction book.
3. If the unit is equipped with an oil-pressure type governor, make sure that the governor actuating oil connection is open and that the governor is set for automatic control.
4. Open all turbine drains.
5. Open the valves on the pump packing gland seals (where such valves are fitted).
6. Open the steam and exhaust root valves.
7. Open the exhaust valve at the pump.
8. Lift all sentinel and relief valves by hand.
9. Open pump suction and discharge valves, and open line valves if necessary.

10. Crack open the steam throttle valve at the pump to free the lines and casing of water. Close the drains when the turbine is free of condensate and admit sufficient steam through the throttle valve to turn the unit over at the minimum speed required to develop and maintain oil circulation in the unit lubrication system. Continue to operate at that speed until the turbine is thoroughly warmed and it is definitely established that everything is working satisfactorily.
11. Open the throttle gradually and bring the unit up to the desired speed, OR FOR MOTOR-DRIVEN PUMPS, push the START button after the pump is lined up and ready to operate.
12. Check the lube system to see that the bearings are getting an adequate supply of oil. Check all gages and thermometers to see that proper pressures and temperatures are being developed.
13. When the lube oil temperature reaches 100° F, cut in the cooling water to the oil cooler. Regulate the flow of cooling water to suit operating conditions. Be sure that all air is vented from the water side of the cooler.
14. On turbine-driven units, make sure that the speed-limiting governor is free and operable. If an overspeed trip is installed, set it and trip it by hand.
15. Adjust pump shaft packing glands and gland sealing needle valves, if overheating or excessive leakoff indicates the need for adjustment.
16. Shift the pump over to governor control, and open the throttle wide to ensure a sufficient quantity of steam for the pump at all loads.
17. Follow all applicable operating instructions given in the manufacturer's instruction book.

It is particularly important to keep a close watch on both pump and turbine during the first few minutes of operation. Pressures, temperatures, and speeds must be checked, so that any dangerous conditions can be spotted

and corrected before damage occurs. The unit should be closely watched until temperatures have reached normal operating values and have leveled off.

The procedure for stopping and securing a rotary pump is as follows:

1. Close the throttle (OR stop the motor).
2. Close the pump discharge and suction valves, and line valves if necessary.
3. Close the exhaust valve at the pump.
4. Open the turbine casing drains.
5. Secure the cooling water to the oil cooler. If a separate lube oil pump is installed, close all oil supply and return valves.
6. Close the steam and exhaust root valves.
7. Close the turbine drains, after the casings and lines are drained.
8. Secure the pump governor actuating line, and open the governor bypass valve.
9. After the pump is secured, check the turbine exhaust pressure gage and the pump suction pressure and vacuum gage. Unusual readings on the turbine exhaust pressure gage indicate that the steam is leaking through the steam supply valve or the exhaust valve, causing pressure to build up inside the turbine casing. On a system which is served by more than one pump, you may occasionally find unusual readings on the pressure and vacuum gage at the suction side of an idle pump. This condition is indicative that oil pressure is being built up inside the idle pump casing because the discharge valve is leaking.

If the pump fails to build up the required pressure, or if it fails to discharge fluid when the discharge valve is open and the pump is up to speed, stop the unit. Check over the pump completely to see that the proper valves are open in the pump and piping system. The trouble may be a faulty relief valve, or a valve disk which has been damaged or hung up. You should also check for loose packing

glands on the pump shaft, loose packing glands on the stems of suction valves, loose strainer covers, and other possible sources of air leakage. See that there are no clogged suction strainers or suction lines which might be causing the trouble. If a motor-driven pump fails to develop pressure when it is first operated after major repairs have been made to the electrical end, check to be sure that the pump is rotating in the proper direction.

Lube Oil Pumps on Auxiliary Machinery

Small lubricating oil pumps are installed on many of the engineroom auxiliary machinery units, such as the main circulator, turbine driven main lube oil pumps, and the feed booster pumps. These lubricating oil pumps are usually positive displacement rotary pumps of the simple gear type. Figure 8–9 illustrates the operating principles of this type of pump.

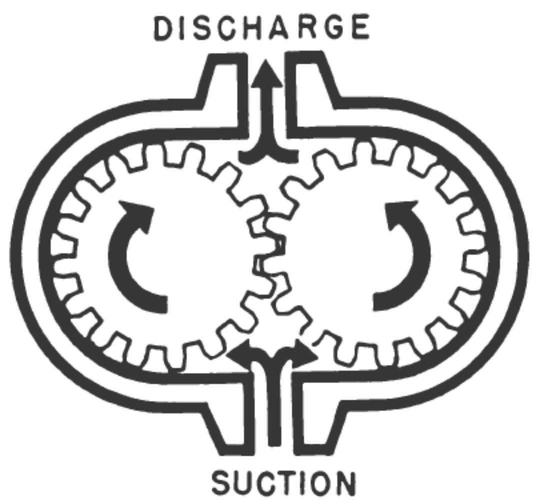


Figure 8–9.—Action of simple gear pump.

A certain amount of maintenance and repair is required to keep these small lube oil pumps in proper condition. You may have to renew the gears, the casing itself, or the gaskets which are sometimes fitted between the casing flanges. It is essential that designed clearances be maintained. Do not attempt to repair this or any other

type of pump without first assembling all pertinent drawings, dimension data, and pump history. Do not attempt to fit a gasket to a lube oil pump which is not designed to have one. If a gasket is to be renewed, be sure that you use one of proper thickness.

Tests and Inspections

The following tests and inspections should be made on rotary pumps, and the results should be entered in the appropriate check-off list or log:

DAILY: Turn the idle pumps by hand.

WEEKLY: Run the pump under power. Lift all relief valves by hand. Check the operation of the discharge check valves (if installed). Check the condition of the lubricating oil; in particular, check for the presence of water in the lube oil.

QUARTERLY: Test all relief valves by steam, water, or oil, as appropriate. Measure thrust bearing clearances, and check the position of pump rotors. Check all foundation bolts and dowel pins. Slowly close the suction valve at the pump and note the amount of vacuum pulled; if the pump fails to produce the required vacuum, it should be opened and repaired as necessary. Check the lube oil system and renew oil and grease.

ANNUALLY: Open the pump, turbine, and reduction gear casings for inspection and cleaning. Measure clearances of all internal wearing parts, and renew parts if necessary.

Perform all daily, weekly, quarterly, biannual, and annual tests and inspections required on the turbine end.

Safety Precautions

The following precautions must be observed in the operation of rotary pumps:

1. See that all relief valves are tested at the appropriate intervals. Be sure that relief valves function at the designated pressures.

2. Never attempt to jack over a pump by hand while the steam or power is on.
3. Do not tie down the overspeed trip, the speed-limiting governor, or the speed-regulating governor. Do not in any way render these devices inoperable.
4. Never operate a positive displacement rotary pump with the discharge valve closed, unless provision is made for adequate discharge.
5. Observe all appropriate safety precautions given in the chapter on auxiliary turbines.

CENTRIFUGAL PUMPS

The basic principles of operation of the centrifugal pump are discussed in *Fireman,* NavPers 10520–A. As you will recall, the centrifugal pump utilizes the throwing force of a rapidly revolving IMPELLER. The liquid is pulled in at the center or EYE of the impeller and is discharged at the outer rim of the impeller.

By the time the liquid reaches the outer rim of the impeller, it has acquired a considerable velocity. The liquid is then slowed down by being led through a volute or through a series of diffusing passages. As the velocity of the liquid decreases, its pressure increases; and thus its kinetic energy is transformed into potential energy.

Types of Centrifugal Pumps

There are many different types of centrifugal pumps, but the two which you are most likely to encounter on board ship are the volute pump and the volute turbine pump.

The VOLUTE PUMP is shown in figure 8–10. In this pump, the impeller discharges into a volute—that is, a gradually widening channel in the pump casing. As the liquid passes through the volute and into the discharge nozzle, a great part of its kinetic energy is converted into potential energy.

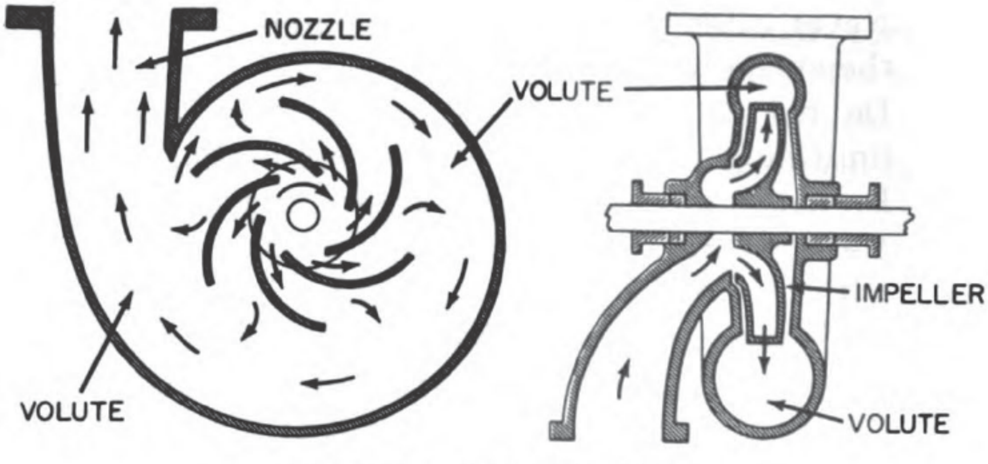


Figure 8-10.—Simple volute pump.

In the VOLUTE TURBINE PUMP, shown in figure 8-11, the liquid leaving the impeller is first slowed down by the stationary diffuser vanes which surround the impeller. The liquid is forced through gradually widening passages in the diffuser ring (not shown) and into the volute. Since both the diffuser vanes and the volute reduce the velocity of the liquid, there is in this type of pump an

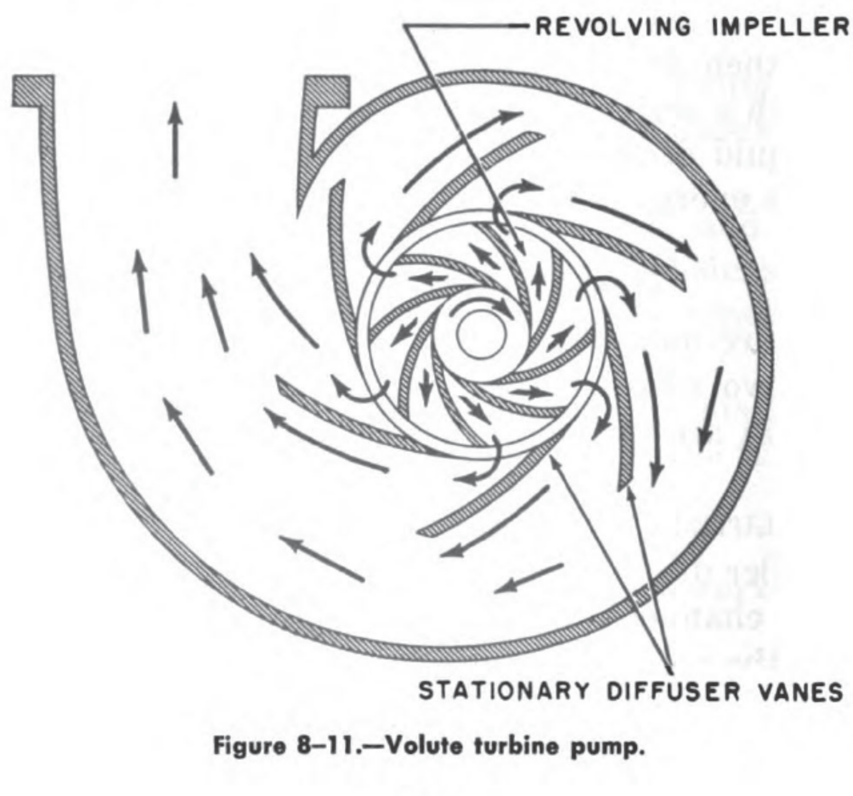


Figure 8-11.—Volute turbine pump.

almost complete conversion of kinetic energy to potential energy.

Centrifugal pumps may be classified in several ways. For example, they may be either SINGLE-STAGE or MULTI-STAGE. A single-stage pump has only one impeller. A multistage pump has two or more impellers housed together in one casing; as a rule, each impeller acts separately, discharging to the suction of the next stage impeller. Centrifugal pumps are also classified as HORIZONTAL or VERTICAL, depending upon the position of the pump shaft.

The impellers used on centrifugal pumps may be classified as SINGLE-SUCTION or DOUBLE-SUCTION. The single-suction impeller allows liquid to enter the "eye" from one direction only; the double-suction type allows liquid to enter the "eye" from two directions. Impellers are also classified as CLOSED or OPEN. Closed impellers have side walls which extend from the eye to the outer edge of the vane tips; open impellers do not have these side walls. Most centrifugal pumps used in the Navy have closed impellers.

Construction of Centrifugal Pumps

As a rule, the casing for the liquid end of a pump with a single-suction impeller is made with an end plate which can be removed for inspection and repair of the pump. A pump with a double-suction impeller is generally made so that one half of the casing may be lifted without disturbing the pump.

Since the impellers rotate at very high speed, they must be carefully machined in order to minimize friction; and they must be balanced in order to avoid vibration. A close radial clearance must be maintained between the outer hub of the impeller and that part of the pump casing in which the hub rotates in order to minimize leakage from the discharge side of the pump casing to the suction side.

Because of the high rotational speed of the impeller and the necessarily close clearance, the running surfaces of both the impeller hub and the casing at that point are subject to relatively rapid wear. To eliminate the need for renewing an entire impeller and pump casing solely because of wear in this location, centrifugal pumps are designed with replaceable wearing rings. One ring is attached to the hub of the impeller, and rotates with the impeller; a matching ring is attached to the casing, and is therefore stationary. The replaceable ring on the hub of the impeller is called the IMPELLER WEARING RING, and the ring attached to the casing is called the CASING WEARING RING. (Wearing rings are shown on the main feed pump illustrated in figure 8–12.)

It should be noted that some small pumps with single-suction impellers are made with a casing wearing ring only, and no impeller ring; in this type of pump, the casing wearing ring is fitted into the end plate.

In many centrifugal pumps, the shaft is fitted with replaceable sleeves. The advantage of using sleeves is that they can be replaced more economically than the entire shaft.

Recirculating lines are installed on some centrifugal pumps to prevent the pumps from overheating and becoming vapor-bound when the discharge is entirely shut off. Seal piping is also installed to cool the shaft and the packing, to lubricate the packing, and to seal the joint between the shaft and the packing against air leakage. A lantern ring spacer is inserted between the rings of the packing in the stuffing box. Seal piping leads liquid from the discharge side of the pump to the annular space within the lantern ring. The web of the ring is perforated so that water can flow in either direction along the shaft, between the shaft and the packing.

Bearings support the weight of the impeller and maintain the position of the impeller, both radially and axially. Most centrifugal pumps have a built-in bearing lubrica-

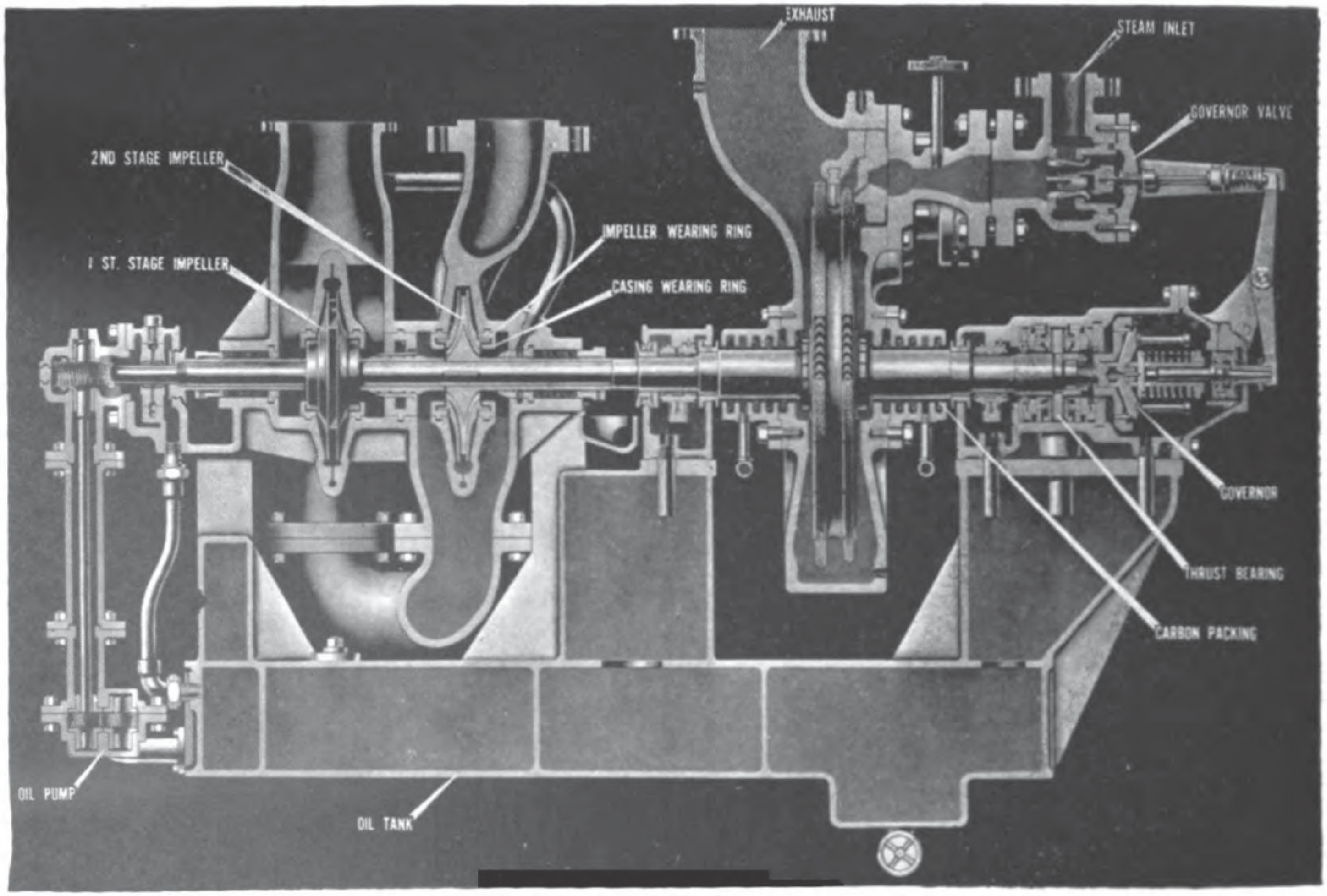


Figure 8–12.—Main feed pump.

tion system, complete with lube oil pump, sump, cooler, strainer, and temperature and flow indicators.

The power end of a centrifugal pump may be either a steam turbine or an electric motor. For most constant-speed applications, the turbine drive has no particular advantage over the motor drive. On naval vessels, however, where reliability and flexibility are essential considerations, most large centrifugal pumps are turbine driven. Smaller pumps, such as those used for in-port or cruising operation, are often motor driven.

The turbines used for centrifugal pumps are usually single-stage impulse turbines. As a rule, high-pressure centrifugal pumps are direct-drive—that is, the impeller rotates at the same rpm as the turbine. However, some low-pressure centrifugal pumps have reduction gears installed between the turbine and the impeller; this allows the turbine to operate at a high speed and the impeller to operate at a lower speed, thus obtaining maximum efficiency from both turbine and pump.

Engineroom Applications

Centrifugal pumps are widely used on board ship for pumping nonviscous liquids. In the engine room you will find several important centrifugal pumps: the feed booster pump, the fire and flushing pump, condensate pumps, auxiliary circulating pumps, and—in some ships —the main feed pump may be located in the engineroom.

FEED BOOSTER PUMPS are used in closed feed systems only. The booster pump takes suction from the deaerating tank and discharges into the main feed pump suction. The booster pump provides a suction pressure of about 35 to 55 psi for the main feed pump, and thus enables the main feed pump to handle feed water at high temperatures, without becoming vapor-bound and losing suction. Feed booster pumps operate at or near constant speed. In the case of a turbine-driven feed booster pump, the speed is maintained approximately constant by the turbine constant speed or speed-regulating governor.

CONDENSATE PUMPS are vertical, one- or two-stage pumps which may be used in closed and open feed systems. These pumps may be turbine-driven or electric motor-driven. The distinguishing features of condensate pumps are the large suction chambers and the large impeller "eye." The area above the impeller eye is vented to the main condenser to prevent the pump from becoming vapor bound. The condensate pump is always located below the condenser, and consequently has a positive suction head into the impeller eye. In the case of a turbine-driven condensate pump, the speed is maintained approximately constant by a constant speed, turbine governor.

Pump turbines equipped with constant speed governors may have, in addition, a safety device known as an OVERSPEED TRIP. The overspeed trip cuts off the steam supply to the turbine after a predetermined speed has been reached, and thus stops the unit. Overspeed trips are usually set to trip out at about 110 percent of normal operating speed.

The FIRE and FLUSHING PUMP is a single-stage, double suction, volute-type centrifugal pump, As a rule, this pump is driven either by an electric motor or by a turbine. In some installations, however, one end of the pump shaft is connected to a motor and the other end is connected to a steam turbine. In all cases, a flexible coupling is used. Sometimes a type of coupling is used which allows the turbine to remain idle while the motor is driving the pump.

A typical MAIN FEED PUMP is shown in figure 8–12. Main feed pumps are of the high-speed, horizontal, turbine-driven type. Main feed pumps usually operate at a discharge pressure of 100 to 150 psig above the maximum steam drum pressure of the boiler. If automatic feed water regulators are installed, the discharge pressure of the main feed pump must be even higher. It is necessary for a main feed pump to operate at varying speeds to maintain a constant discharge pressure under all conditions of load. A pump pressure-regulating gov-

ernor automatically regulates the admission of steam to the turbine so as to control the discharge pressure.

PROPELLER PUMPS are used primarily where there is a large volume of liquid with a relatively low head pressure. These pumps are usually limited to use where the total head does not exceed 40 to 60 feet.

The chief use of the propeller pump is for the main circulating pump (fig. 5–11). The main condenser circulating pump on most ships has an emergency suction for pumping out the engineroom.

The main condenser circulating pump illustrated in figure 5–11 is of the vertical propeller type. The pump unit consists of three major parts: the propeller, together with its bearings and shaft; the pump casing; and the driving unit.

The propeller of this pump is a two-bladed screw propeller having a large pitch; the blades are thick at the roots and flare out toward the tips. The blades and hubs are cast or forged in one piece, and are then machined and balanced. The lower shaft bearing is a water-lubricated sleeve-type bearing; the shaft packing gland prevents excessive leakage of water between the casing and the shaft. An upper steady bearing consists of a fixed internal steel journal, about which a babbitted bearing revolves; and this revolving bearing forms the hub of the double-helical reduction gear. An extension of the upper hub of the bull gear is keyed to the vertical shaft and to the thrust bearing collar.

The pump illustrated in figure 5–11 is driven by a geared, vertical, axial-flow, single-reentry turbine. This turbine is described in chapter 3, Main and Auxiliary Turbines, of this training course.

Because of the similarity of the centrifugal and propeller type pumps, the information given concerning care, maintenance, inspection, and precautions for centrifugal pumps is equally applicable for propeller pumps.

Operation of Centrifugal Pumps

The operating instructions for centrifugal pumps vary somewhat from one type to another. Before attempting to operate any pump, therefore, you should read the posted operating instructions, read the valve labels, and check the piping markings.

The posted instructions for starting and operating a centrifugal pump will probably read something like this:

1. Check the lube oil level in the sump tank or bearing housing. Fill oil cups or reservoirs, if fitted. Rotate the handle of the lube oil filter before starting the pump, and at least once during each watch.
2. Lubricate the linkage and slides on the speed-limiting governor. If a gravity-feed oil cup is provided for the end bearing of the governor spindle, lift the snap tip of the needle valve to a vertical position; and check to be sure that oil is being fed at the proper rate—about 5 to 10 drops per minute, or as recommended by the manufacturer's instruction book.
3. Open the pump suction valve.
4. Check the suction pressure.
5. Make sure that the recirculating valve (if installed) is locked in the OPEN position.
6. Open vents on the pump end.
7. Open all drains on the steam end.
8. Open the turbine exhaust valve.
9. Open the bypass around the constant-pressure pump governor.
10. Crack open the turbine throttle (OR start the motor).
11. Close the drains when steam blows through them.
12. Increase the throttle opening and run the pump fast enough so that the lube oil will begin to circulate.

13. Make sure that the speed-limiting governor is free and operable. If an overspeed trip is installed, set it and trip it by hand.
14. When the vents on the pump end discharge solid streams of water, close them.
15. Continue to run the pump at moderate speed until the oil temperature reaches 100° F. Be sure to keep the pump running fast enough to maintain an adequate discharge pressure; if the discharge pressure is too low, the pump packing will not be lubricated properly.
16. When the lube oil temperature reaches 100° F, cut in the cooling water to the oil cooler. Regulate the flow of cooling water to suit operating conditions. Be sure that all air is vented from the water side of the cooler.
17. When ordered to cut in the pump, close the constant-pressure governor bypass valve and open the throttle valve all the way. Bring the discharge pressure up to the required line pressure by putting tension on the constant-pressure governor spring, and slowly open the discharge valve.

If the pump fails to build up pressure, notify the PO of the engineroom watch. If the pressure goes too high, secure the pump and cut in another one; or, if the pump must be operated, use manual control.

Instructions for stopping and securing a centrifugal pump will, in general, read something like this:

1. Release tension on the constant-pressure governor spring.
2. Close the throttle valve (OR stop the motor).
3. Close the exhaust valve.
4. Close the suction valve.
5. Close the pump discharge valve.
6. Open the turbine drains.
7. Close the drains, after the turbine is completely drained.
8. Secure the cooling water to the lube oil cooler.

Care and Maintenance of Centrifugal Pumps

Some of the information which you must have in order to give proper care and maintenance to centrifugal pumps is given in this section. For further details, and for specific information on any one pump, you should consult the *Bureau of Ships Manual* and the appropriate manufacturer's instruction books. Before attempting to repair a pump, you should assemble the pump history and all pertinent drawings and dimensional data.

LUBRICATION is essential for the proper operation of centrifugal pumps, and inadequate lubrication is a primary cause of pump failure. The supply of oil to the bearings must be checked frequently during each watch. Grease cups and bearing housings must be kept filled with lubricant, and free of water or other foreign matter. Lubricating oil should be changed whenever it foams excessively, becomes emulsified, or contains dirt or sludge.

Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When you are operating a centrifugal pump, be sure that there is always a slight trickle of water coming out of the stuffing box or seal.

STUFFING BOX PACKING should be renewed about once every 2 months. You should install the packing so as to give a uniform thickness all around the shaft sleeves. When installing new packing, pack the stuffing box loosely and set up lightly on the packing gland; then, when the pump is in operation, tighten the gland in steps so as to compress the packing gradually. This procedure will prevent excessive heating and possible scoring of the shaft or shaft sleeves.

Some stuffing boxes are fitted with packing beyond the lantern ring; and this packing must be replaced when the stuffing box is being repacked. It is important, also, to make sure that the sealing water connection to the lantern ring is not blocked off by the packing.

Unusually rapid wear of the packing may be caused by roughness of the shaft. A rough shaft should be sent to the machine shop for a finishing cut to smooth the surface; or, if the surface is very rough, the sleeves should be renewed.

WATER FLINGERS are fitted on shafts outboard of stuffing box glands, to prevent water from following along the shaft and entering the bearing housings. The flingers must be tightly fitted. If the flingers are fitted on the shaft sleeves, rather than on the shaft, make sure that no water is allowed to leak under the sleeves. If leakage does occur, a fiber washer should be fitted between the end of the sleeves and the shaft shoulder, and all clearances between shaft and sleeves should be filled with tallow.

The clearances between IMPELLER WEARING RINGS and CASING WEARING RINGS must be maintained within the specified tolerances. Clearances are shown on the manufacturer's plans. When clearances exceed the specified figures, the wearing rings must be replaced. This job can be done by ship's force, but it requires the complete disassembly of the pump. If it is necessary for you to undertake this job, be sure to follow the manufacturer's instruction book carefully. Improper fitting of the rings or incorrect reassembly of the pump can result in serious damage.

SHAFT ALINEMENT must be checked frequently. If shafts are out of line, the unit must be realined in order to prevent shaft breakage and damage to bearings, pump casing wearing rings, and throat bushings. Shaft alinement should be checked with all piping in place; and due allowance must be made for the change in position of parts from cold-check conditions to hot-operating conditions.

Tests and Inspections

The following tests and inspections should be made on centrifugal pumps, and the results should be entered in the appropriate check-off list or log:

DAILY: Turn idle pumps by hand.

WEEKLY: Run the pump under power. Lift all relief valves by hand. Check the operation of the discharge check valves. Determine the condition of the lubricating oil.

QUARTERLY: Test all relief valves by steam, water, or oil, as appropriate. Measure the thrust bearing clearance. Check the axial position of the pump impellers. Check bearing clearances by leads or bridge gage readings. Examine and set up on all foundation bolts; secure all foundation dowel pins. Check all water-lubricated bearings and shafts for wear and scoring. Clean the lubricating system and renew oil or grease.

ANNUALLY: Open the pump, turbine, and reduction gear casings for inspection and cleaning. Check clearances of casing throat bushings and of impeller and casing wearing rings; renew if necessary. Examine all impellers, diffusers, turbine rotors, turbine blading, carbon packing, shafts, and shaft sleeves.

Perform all daily, weekly, quarterly, biannual, and annual tests and inspections required on the turbine end.

Safety Precautions

The following safety precautions must be observed in connection with the operation of centrifugal pumps:

1. See that all relief valves are tested at the appropriate intervals. Be sure that relief valves function at the designated pressures.
2. Never attempt to jack over a pump by hand while the steam valve to the pump is open or while the power is on.
3. Do not tie down the overspeed trip, the speed-limiting governor, or the speed-regulating governor. Do not in any way attempt to render these devices inoperable. Be sure that speed-limiting and speed-regulating governors are properly set.

4. Do not use any boiler feed system pump for any service other than boiler or feed water service, except in emergency.
5. Observe all appropriate safety precautions given in the chapter on auxiliary turbines.

PUMP REGULATING DEVICES

Many pumps are fitted with devices for regulating either speed or discharge pressure, or both. As a rule, these regulating devices or governors are not used on reciprocating pumps; but practically all rotary and centrifugal pumps have some type of governor.

Constant Speed Governor

Turbine-driven condensate and feed booster pumps are controlled by a CONSTANT-SPEED or SPEED-REGULATING GOVERNOR. It holds the speed of the turbine relatively constant under all conditions from no-load to overload, up to the speed for which the governor is set, but it does not allow operation in excess of 105 percent of normal operating speed.

Most constant-speed governors are of the centrifugal-weight type. Figure 8–13 shows a centrifugal-weight type constant speed governor for a condensate pump. The governor shaft is driven directly by an auxiliary shaft in the condensate pump reduction gear and rotates at the same speed as the pump shaft. Two flyweights are pivoted to a yoke on the governor shaft and carry arms which bear on a push rod assembly. The push rod assembly is held down by a strong spring. Centrifugal force on the flyweights causes them to be thrown outward. This lifts the arms, which pivot on rollers, against the spring tension on the governor stem when the speed of rotation approaches the speed for which the governor is set. (Some flyweights pivot on knife edges rather than rollers.) If the turbine speed begins to exceed that for which the governor is set, increased centrifugal force acting on the

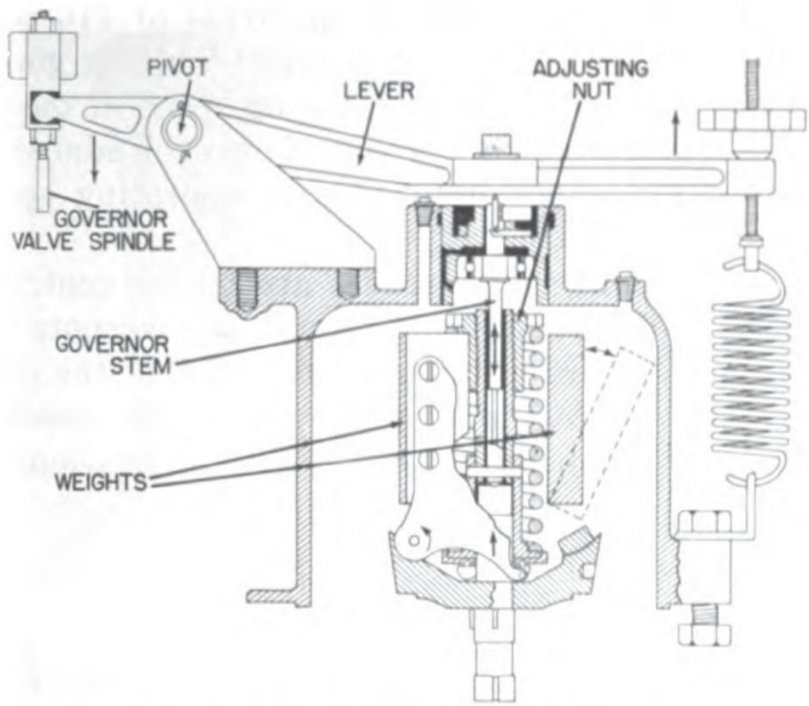


Figure 8–13.—Turbine governor, main condensate pump.

rotating flyweights will cause them to move farther out, and thereby cause the governor valve to throttle down on the steam. On the other hand, when the turbine slows down, as from an increase in load, the centrifugal force on the flyweights is reduced, and the governor push rod spring acts to pull the flyweights inward. This rotates the lever about its pivot and opens the governor valve, thus admitting more steam to the turbine with a resultant speed-up of the turbine until normal operating speed is reached. Thus the governor controls the turbine speed within very close limits.

Speed Limiting Governor

Turbine-driven engineroom pumps such as main feed, main circulator, and fire and flushing pumps are controlled by a SPEED-LIMITING GOVERNOR. This is essentially a safety device for variable-speed units. It allows the turbine to operate under all conditions from no-load to overload, up to the speed for which the governor is set,

but it does not allow operation in excess of 110 percent of normal operating speed. The speed-limiting governor is adjusted to the maximum operating speed of the pump turbine, and therefore has no control over the admission of steam until the upper limit of safe operating speed is reached.

Most speed-limiting governors are of the centrifugal-flyweight type, but some speed-limiting governors of the oil-pressure type are also used. Operation of the centrifugal-flyweight speed-limiting governors is essentially the same as the constant-speed governor previously described.

EDUCTORS

In the previous pages, the pumps under discussion were either motor- or turbine-driven. Now we come to a group of pumps known as EDUCTORS. They have no moving parts and are used to drain water from bilges and ballast tanks.

Eductors are used where it is desired to pump large volumes of water at high rates and with low to moderate discharge pressures. Water is pumped through the pressure hose into the eductor and then forced through a jet. Figure 8–14 illustrates a fixed-type eductor which is similar to the portable eductors found in damage control lockers. All the water which enters the large end of the jet must go out the small end, but since the exit end is smaller than the entrance end, the water leaving the jet must of necessity have a greater velocity than it had upon entering the jet. The venturi-tube shape of the diverging nozzles causes a low-pressure area, and thus a suction is created which draws water through the strainer and entrains it through the diverging nozzle. This assures a constant flow through the suction hose and a constant suction through the strainer.

Eductors may also be used for salvage work and on fog foam equipment. Eductors will operate when en-

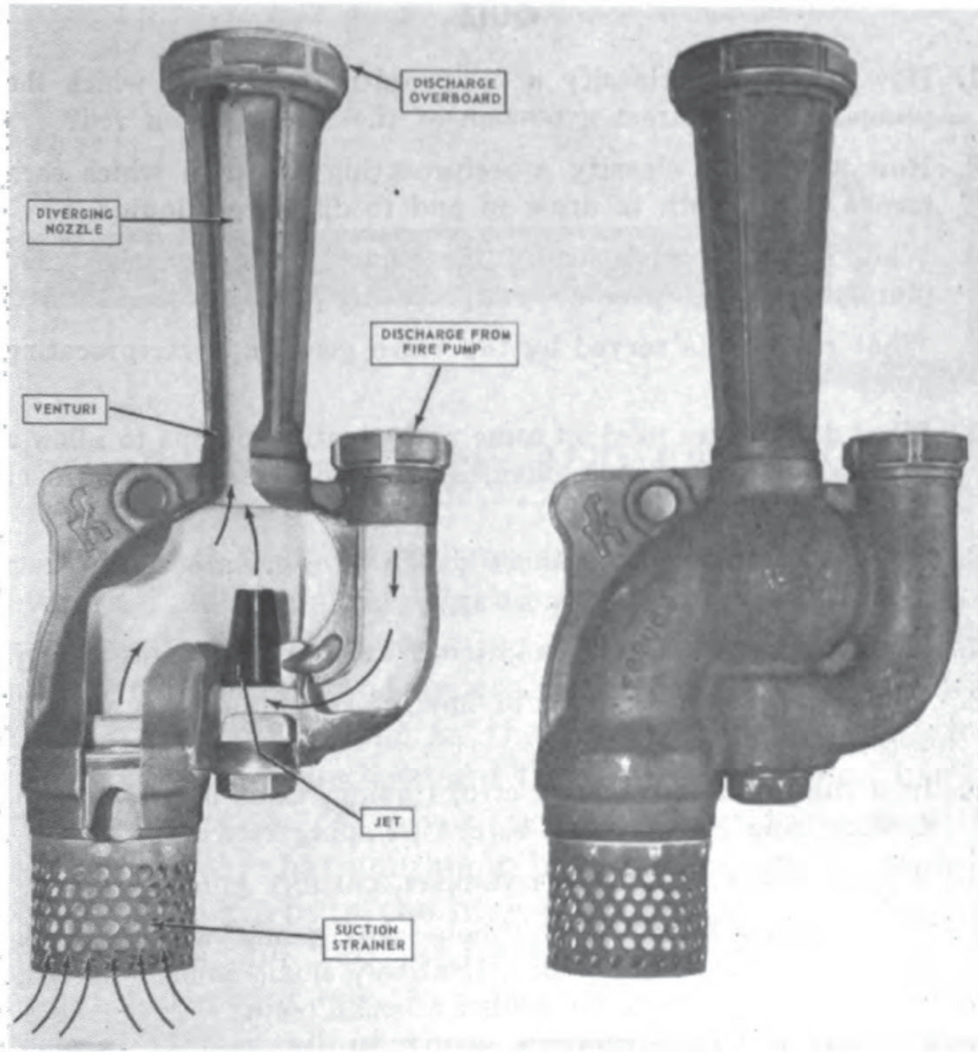


Figure 8–14.—Operating principle of fixed-type eductor.

tirely submerged in a flooded compartment and will discharge against a moderate pressure.

Though fire and bilge pumps are still being installed in new naval vessels, fixed-type eductors (fig. 8–14) are now the principal means of pumping water overboard through the drainage system. By the use of eductors, centrifugal fire pumps can serve as drainage pumps without having to run the risk of fouling the pump with debris present in the bilges—particularly so in cases where there has been battle damage to a ship.

QUIZ

1. How would you classify a reciprocating pump in which the pump rod is a direct extension of the steam piston rod?
2. How would you classify a reciprocating pump in which each stroke serves both to draw in and to discharge liquid?
3. What is the relative size of the steam piston and the pump plunger, in a high-pressure reciprocating pump?
4. What purpose is served by the valve gear on a reciprocating pump?
5. What devices are used on some reciprocating pumps to allow a gradual, rather than sudden, drop in discharge pressure at the end of each stroke?
6. By what means could a short stroke on a reciprocating pump cause the pump to stop operating?
7. How can the stroke be lengthened on a reciprocating pump?
8. What controls the amount of flow in an axial-piston variable stroke pump?
9. In a radial-piston variable stroke pump, what position of the floating ring is necessary before pumping can occur?
10. What is meant by a POSITIVE-DISPLACEMENT pump?
11. For a given size, which simple gear pump will have the greater capacity—one with a relatively small number of large teeth, or one with a large number of small teeth?
12. In a lobe-type pump, what two purposes are served by having replaceable inserts at the extremities of the lobes?
13. What two types of centrifugal pumps are commonly used on board ship?
14. In a centrifugal pump, where is the kinetic energy of the liquid converted into potential energy?
15. Why is the condensate pump vented to the main condenser?
16. How often should centrifugal pump stuffing box packing be renewed?
17. When the centrifugal-flyweights of a constant-speed governor are thrown outward, what is the effect on a turbine-driven feed booster pump?
18. Which shipboard pumps have no moving parts?

CHAPTER 9

PIPING, VALVES, AND PACKING

As a Machinist's Mate, you should know about piping, fittings, insulation, valves, and packing. Aboard ship you are responsible for the routine maintenance of this equipment in your assigned spaces. In addition, the qualifications for advancement in the Machinist's Mate rating require that you understand the construction and use of the major types of valves, and that you know how to repair valves; that you know how to disassemble, repair, and replace parts in the high-pressure and low-pressure steam lines; how to repair insulation and lagging on steam lines, and how to select gasket and packing materials. Unless all of these elements are kept in good working condition, the connected units of equipment and machinery cannot be operated efficiently, and the safety of the ship and her personnel may be imperiled.

PIPING DEFINITIONS

In the routine operations aboard ship there is frequent misuse of the terms PIPE, TUBING, and PIPING by strikers and inexperienced naval personnel. As a step toward correcting the misuse of these three terms, the following definitions are offered.

1. A pipe is made of metal such as cast iron, wrought iron, steel, copper, or brass and designated for size by its nominal inside diameter (ID) in accordance with stand-

ard IRON PIPE SIZE (IPS), expressed in inches or fractions of an inch from $\frac{1}{8}$ inch to 12 inches. Pipe is designated in three grades or weights of wall thickness as STANDARD, EXTRA STRONG, or DOUBLE EXTRA STRONG. The outside diameters (OD) are the same for each of the three wall thicknesses of any pipe with a given IPS dimension, while the actual ID of these three pipes will differ. When the ID measures more than 12 inches, the pipe is designated by its OD.

For example, a 1 inch standard pipe will have an ID slightly over 1 inch, while 1 inch extra strong and 1 inch double extra strong pipes will have lesser ID's due to their greater wall thickness. The identical OD's permit standardization in pipe dies and taps.

2. TUBING, unlike pipe, is designated for size by its nominal OD dimension; specified for wall thickness in decimals of an inch; and primarily intended for joining by such methods as flanging, rolling, welding, soldering, or brazing. Because of the thinner walls of tubing, it is much more flexible than the thicker-walled pipe. Refrigeration piping systems are examples of the shipboard use of tubing.

3. PIPING is an assembly of pipes or tubing, and fittings, forming a whole or composite part of a system designed for transferring fluids (water, steam, gas, oil, etc.).

Piping Materials

Materials generally used in the manufacture of pipes and tubing for naval use are steel, low alloy steel, copper, brass, and various cupro-nickel alloys. The nonferrous (not derived from iron) piping is used for transferring such fluids as steam condensate, fresh and salt water, lube oil, hydraulic liquids, compressed air and refrigerant liquid and vapor. Steel piping (ferrous metal) is used for transferring water, fuel oil, and steam. High-pressure high-temperature steam is transferred in alloy steel piping.

The piping materials must be carefully selected from specified standards (BuShips Schedule for Piping Systems)—not according to appearance. For example, the 7-inch steel tubing employed for transferring 400 psi, 650° F steam may look the same to you as the 7-inch steel tubing employed for transferring 600 psi, 850° F steam. The material of the first, however, may be carbon steel; whereas that of the second must be molybdenum alloy steel, capable of resisting high temperature and pressure.

PIPE FITTINGS

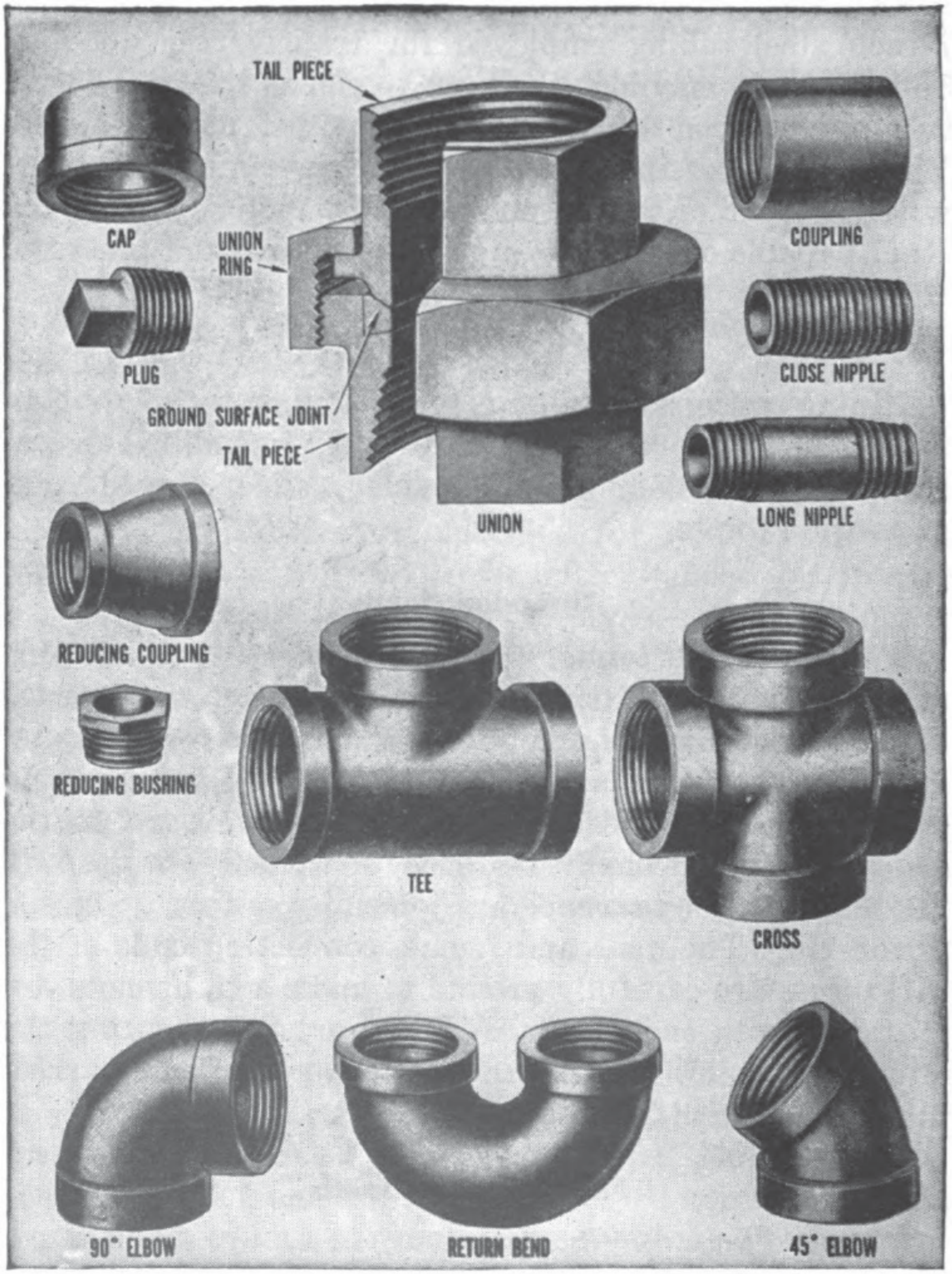
Piping sections of the proper size and material are connected by various standard fittings, including several types of threaded, bolted, welded, silver-brazed, and expansion joints.

Threaded Joints

The threaded joints are the simplest type of pipe fittings. Threaded fittings (fig. 9–1) are not widely used aboard modern ships except in low pressure water piping systems. The union is used a great deal for joining piping up to 2 inches in size. The pipe ends connected to the union are threaded, silver-brazed, or welded into the TAIL PIECES; then the two ends are joined by setting up on the union ring. The male and female connecting ends of the tail pieces are carefully ground to make a tight metal-to-metal fit with each other. Welding or silver-brazing the ends to the tail pieces prevents contact of the carried fluid or gas with the union threading.

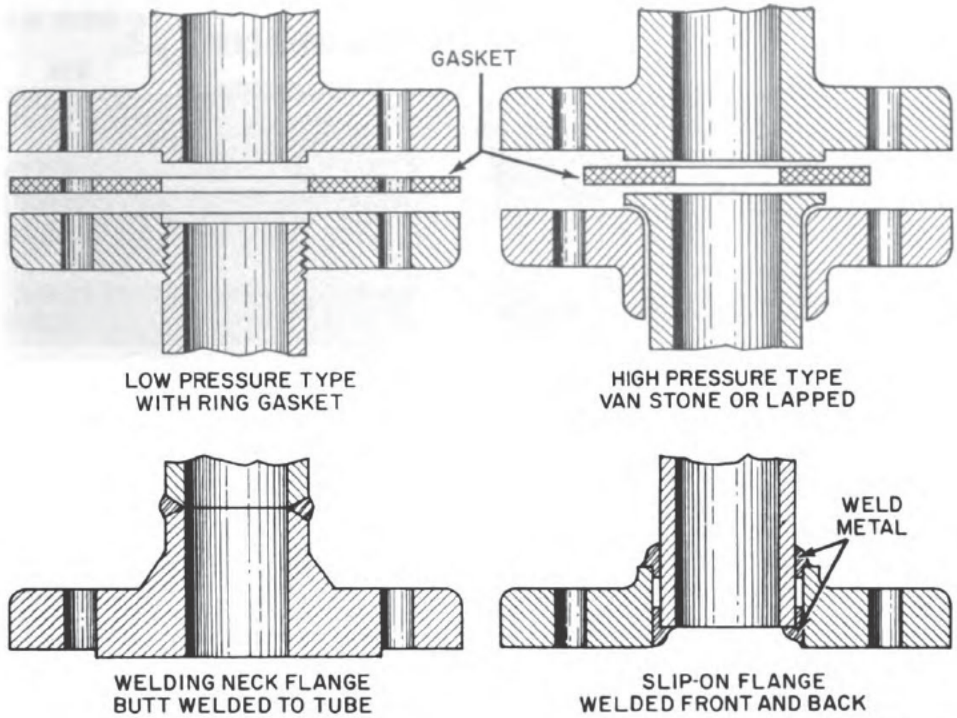
Bolted Flange Joints

Bolted flange joints (fig. 9–2) are suitable for all pressures now in use. The FLANGES are attached to the piping by welding, brazing, screw threads (for some low-pressure piping), or rolling and bending into recesses. Those illustrated are the most common types of flange joints used. The same types of standard fitting shapes



Courtesy of U. S. Naval Institute

Figure 9–1.—Threaded pipe fittings.



Courtesy of U. S. Naval Institute

Figure 9–2.—Bolted flange piping joints—illustrating four different types.

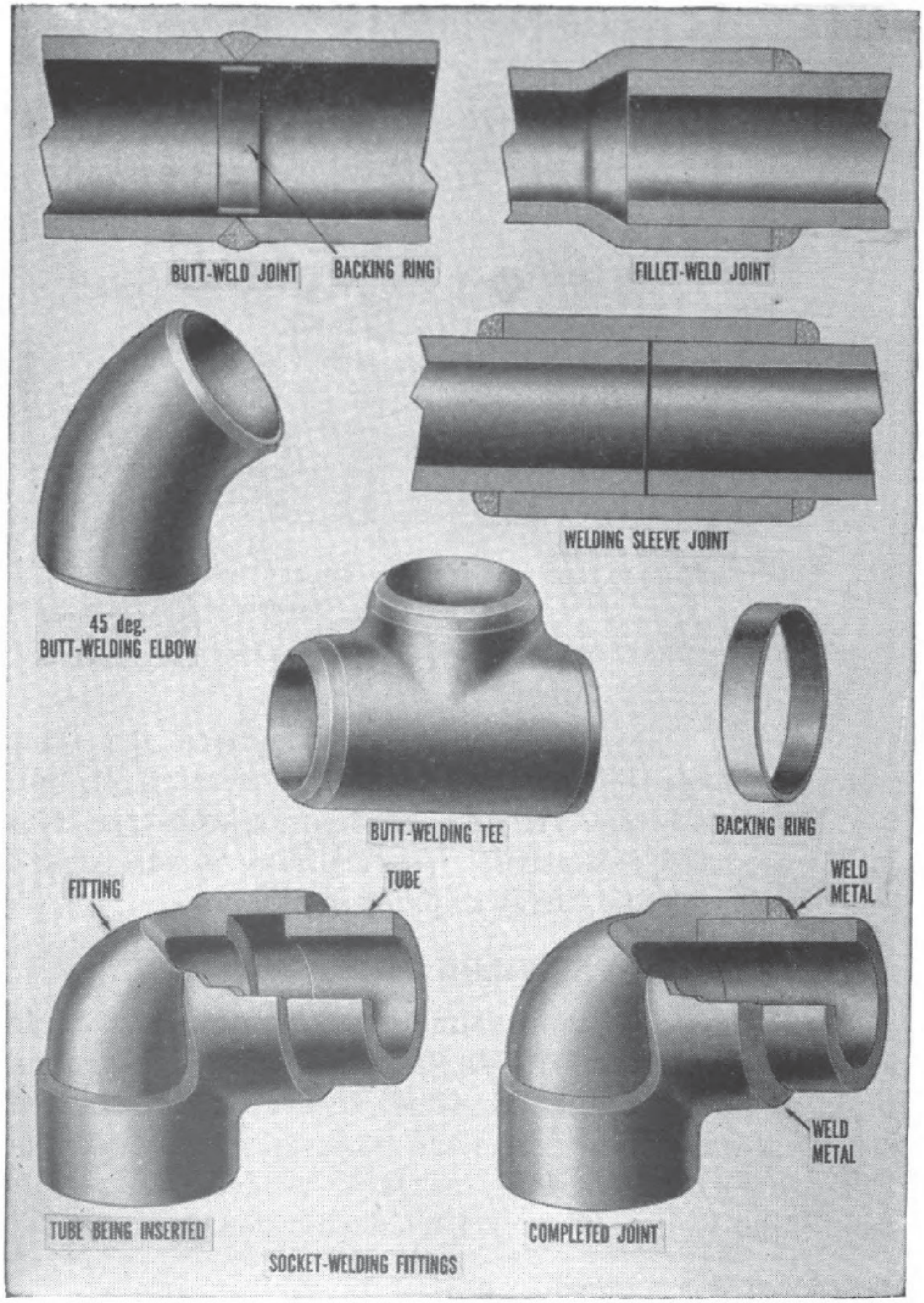
(tee, cross, elbow, etc.) are manufactured for flange joints, such as the threaded fittings illustrated in figure 9–1. The Van Stone type and the welding neck-type flange joints are used extensively where piping is subjected to high pressures and heavy expansion strains.

Welded Joints

The majority of joints found in subassemblies of piping systems are welded joints, especially in high-pressure piping. The welding is done according to standard specifications which define the materials and techniques. There are three general classes of welded joints—butt-weld, fillet-weld, and socket-weld (fig. 9–3).

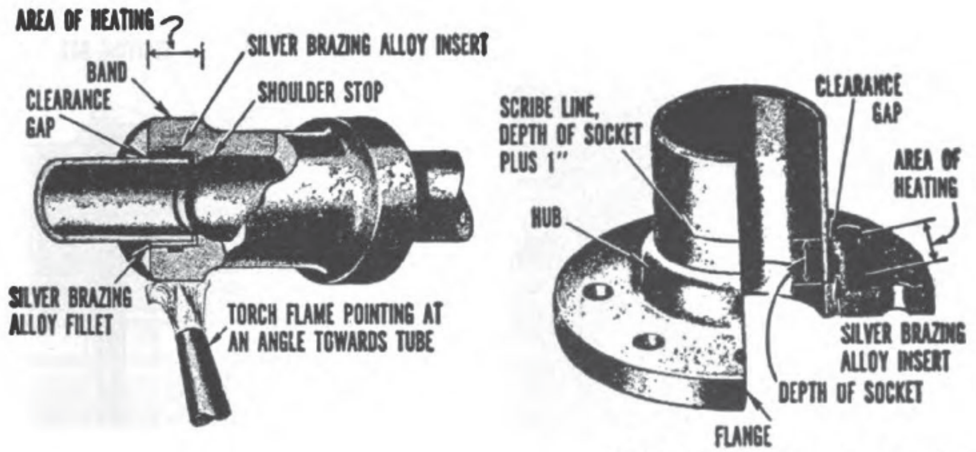
Silver-Brazed Joints

Silver-brazed joints (fig. 9–4) are commonly used for joining nonferrous piping in the pressure and temperature range where its use is practicable. These practical



Courtesy of U. S. Naval Institute

Figure 9–3.—Welded piping joints—illustrating various types in use.



Courtesy of U. S. Naval Institute

Figure 9–4.—Silver-brazed piping joints.

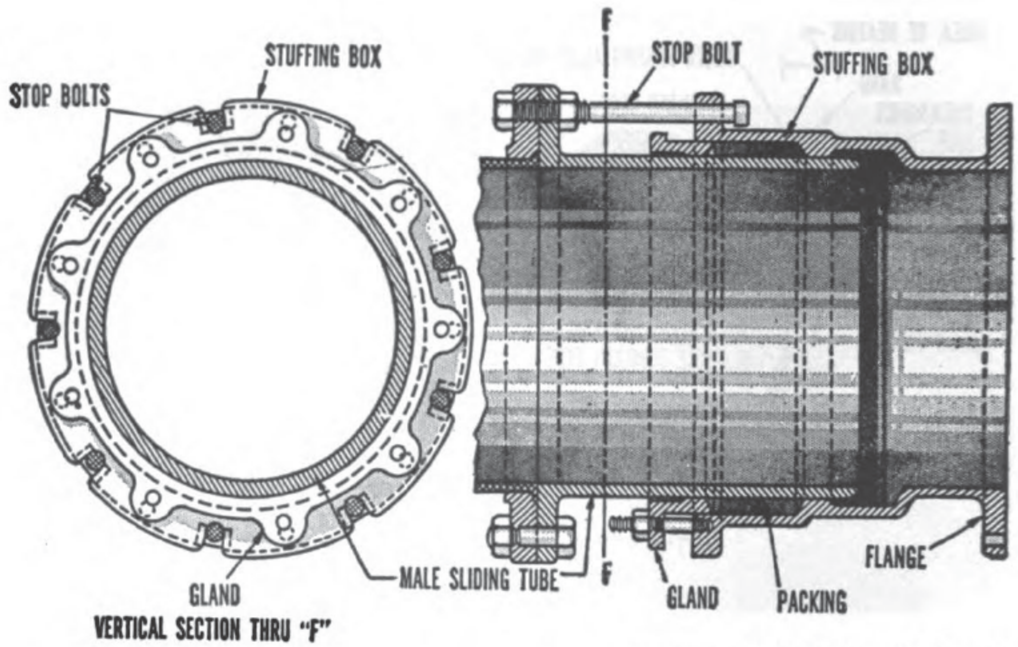
factors limit this joint's use to steam lines not exceeding 425° F; for cold lines, these fittings may be used for pressures up to 3000 psi. The alloy is melted by heating the joint with an oxyacetylene torch. This causes the molten metal to fill the few thousandths of an inch annular space between the pipe and the fitting.

Expansion Joints

Expansion joints of various types are installed at suitable intervals in long steam lines, because of the expansion and contraction of metal subjected to a wide range of temperature. The types include the slip joint, expansion bends, corrugated joints, and bellows joints.

The SLIP JOINT (fig. 9–5) is used for low pressures, such as auxiliary exhaust piping, and consists of a stuffing box, packing gland, male sliding tube, female receptacle tube, and stop bolts (to prevent separation of male and female sections of the joint).

EXPANSION BENDS are employed for high-pressure and high-temperature steam piping in preference to the slip joint. Expansion bends are merely loops of piping of proper length and configuration to take up the changes in pipe length caused by temperature changes. The ex-



Courtesy of U. S. Naval Institute

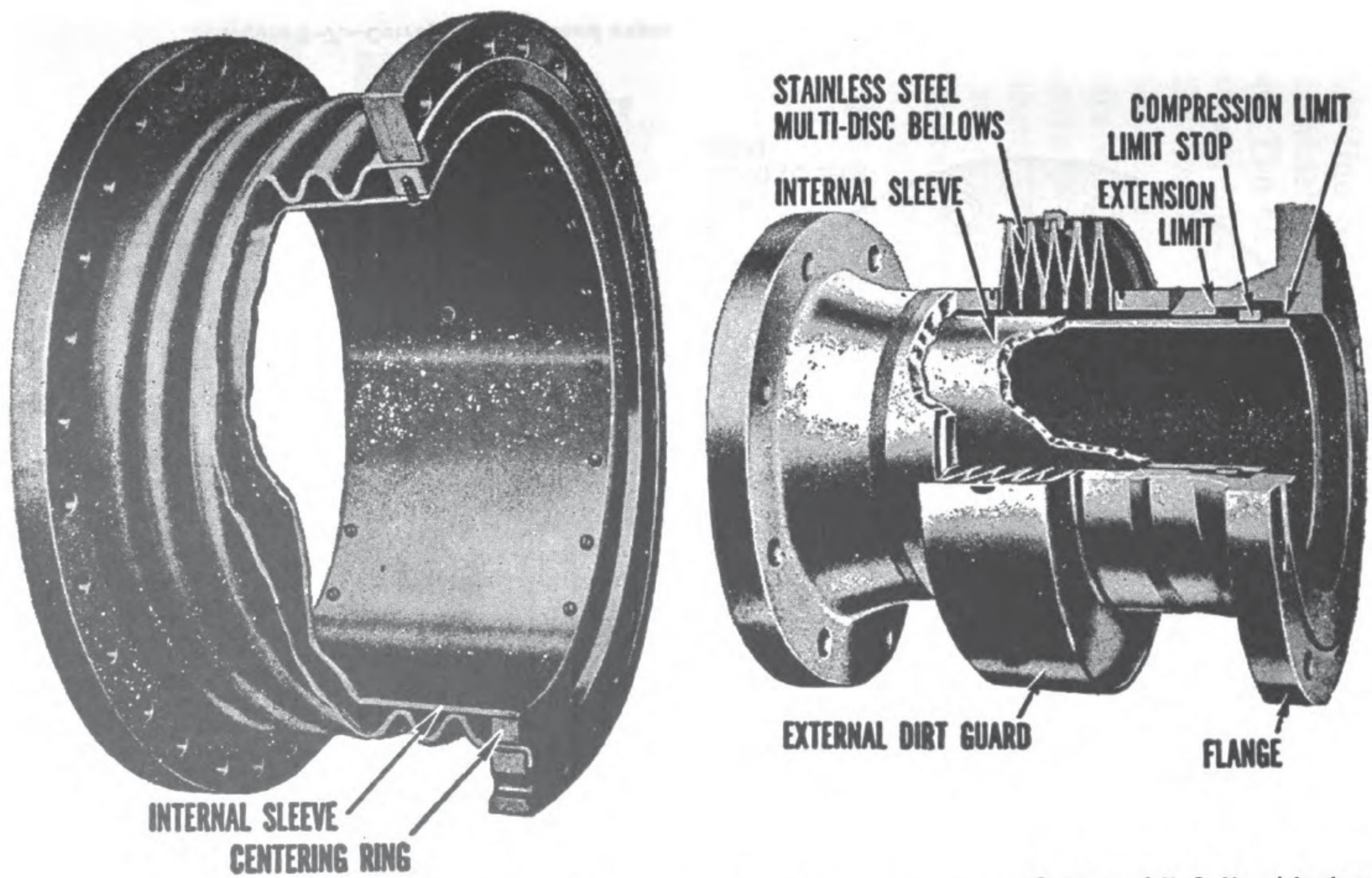
Figure 9–5.—Expansion piping joints: slip type.

pansion bends take many shapes—most common are the U-bend, Z-bend, and L-bend.

The CORRUGATED and BELLOWS TYPES of expansion joints (fig. 9–6) are used for both medium and high pressures and temperatures. The principle of these joints is obvious: the expansion-contraction movement is absorbed by the changing curvature of the corrugations or bellows (as with an accordion). The internal sleeves, free to slide axially in these joints, serve to prevent excessive turbulence and erosion of the expansion parts. Figure 9–7 illustrates a corrugated BULKHEAD EXPANSION JOINT, which is designed to provide for both radial and axial movement of piping, with respect to the bulkhead.

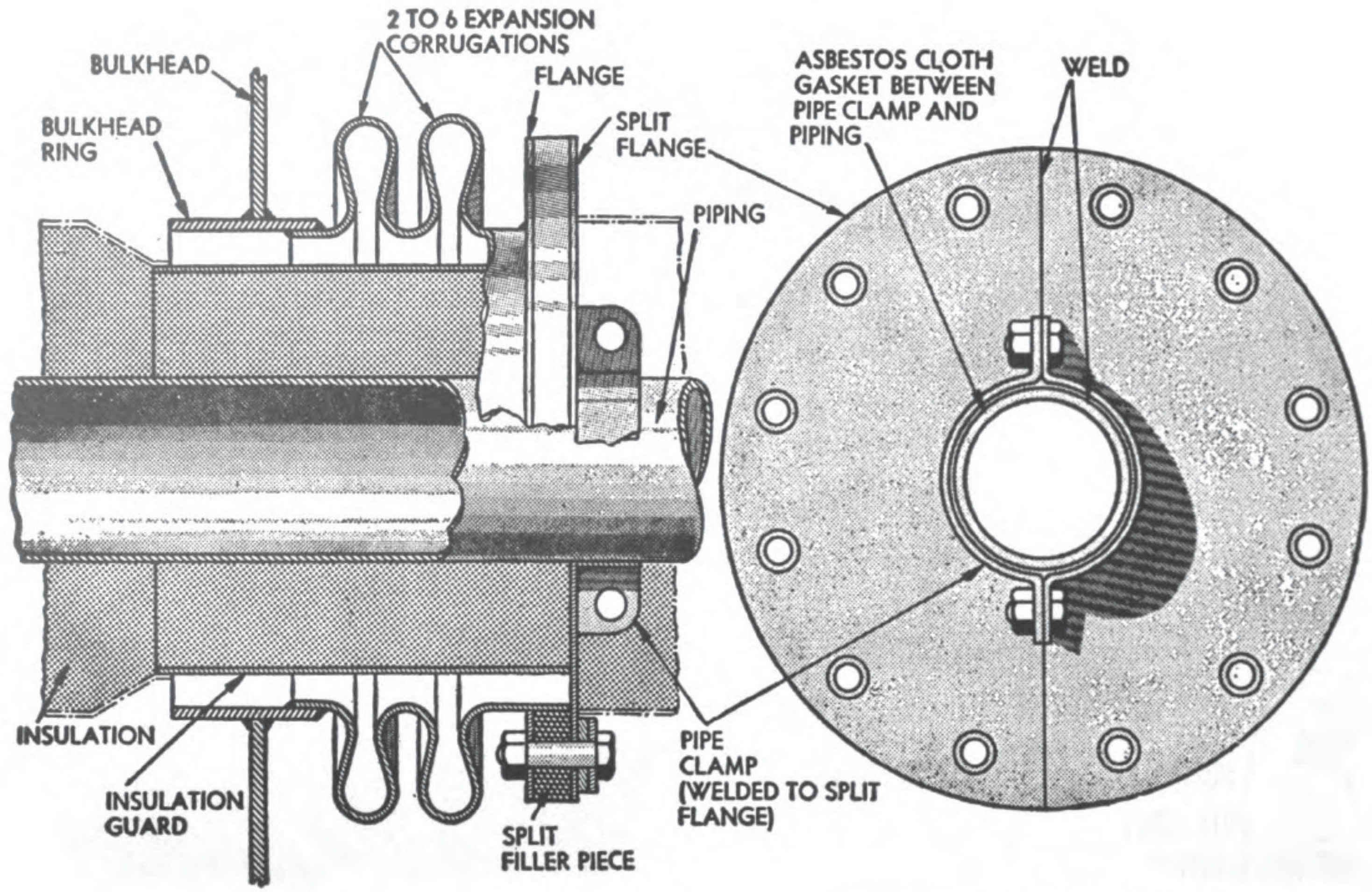
Pipeline Strainers

Strainers are fitted in all piping lines to prevent the passage of grit, scale, dirt, and other foreign matter. Such matter could obstruct pump or throttle valves, or damage machinery parts. Various types of strainers are used, depending upon the service intended.



Courtesy of U. S. Naval Institute

Figure 9–6.—Corrugated type and bellows type expansion joints.

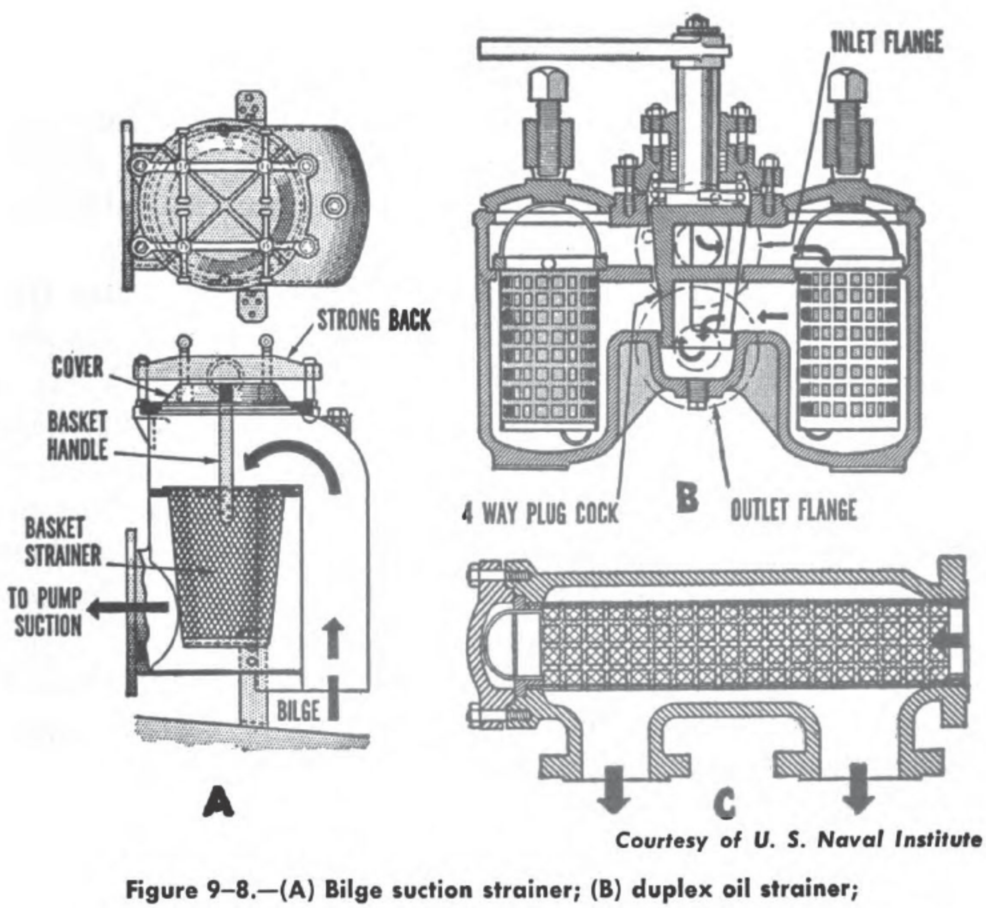


Courtesy of *U. S. Naval Institute*

Figure 9–7.—Corrugated bulkhead expansion joint, showing details of installation.

Figure 9–8A illustrates a common BILGE SUCTION STRAINER. This strainer is located in the bilge pump suction line between suction manifold and pump. Any debris which enters the piping will collect in the strainer basket. The basket is removed for cleaning by loosening the strong-back screws, removing the cover, and lifting out the basket by its handle. These strainers should be cleaned at least every 24 hours while in port, and every 4 hours while under way.

Figure 9–8B illustrates a DUPLEX OIL STRAINER, used ordinarily in fuel or lube-oil lines, where it is important that an uninterrupted flow be maintained. The flow may be diverted from one strainer basket to the other, while one is being cleaned. The shut-off device works on the principle of a four-way cock.



Courtesy of U. S. Naval Institute

Figure 9–8.—(A) Bilge suction strainer; (B) duplex oil strainer; (C) manifold steam strainer.

Figure 9–8C illustrates a MANIFOLD STEAM STRAINER. This type of strainer is desirable where space is limited, since it eliminates the use of separate strainers and their fittings. The cover is located so that the strainer basket can be easily removed for cleaning.

A clean SPARE STRAINER basket of correct size (plainly marked or tagged) should be kept convenient to each strainer location. If the removed basket is heavily encrusted with foreign matter, clean the strainer with a steam jet or boil in a boiler compound solution.

Assembling High-Pressure Steam Lines

Flange faces must not only be in perfect alinement, but they must be free from all dirt, grit, burrs, and nicks which may cause trouble in the joint. Flange faces may be coated with a preservative which must be removed with a suitable solvent. Burrs, nicks, and uneven surfaces can be removed by dressing the faces with an oilstone. The metallic-asbestos spiral wound gasket you insert between the flanges must also be clean. The flange faces should be drawn up with alloy stud bolts and nuts suitable for high temperatures.

The alloy stud bolts suitable for high-temperature use may be identified in two ways: (1) the thread runs the entire length of the body, and one end of the bolt has a small center hole recess; and (2) the bolt is stamped on one end with either an H or an A.

Nuts for high-temperature use have either an H or an A stamped on the crown for identification. If the nut does not have either one of these identifying letters, do NOT use the nut on high-pressure steam lines.

The procedure for making up a flanged joint is similar to but the reverse of that which is used to break a flanged joint. Two diametrically opposite bolts are set up fairly tight, then, 90° around the flange from the first bolts, a second pair is inserted and tightened. The remaining bolts are treated in a similar manner. Each bolt is then in turn

evenly set up to the required bolt tension. (Use a torque wrench to measure for correct tightening tension or a micrometer to measure elongation of the studs. For this latter technique refer to the *Bureau of Ships Manual,* chapter 48.)

PIPING CARE AND MAINTENANCE

Reasonable care must be given the various piping assemblies, as well as the machinery connected by the piping. All joints, valves, and cocks in the lines must be examined frequently, and kept tight. On active ships, the main feed and salt water piping must be tested quarterly, under full working pressure, and for a reasonable length of time, for any leaks and other defects. On inactive ships, the piping must be kept drained, and no pressure tests should be run. The piping on any ship should not be subjected to strains by being used for hand or foot holds, by having chain falls secured to them, or by being used for supporting weights.

Where piping passes through decks or bulkheads, and a possibility exists for movement of one with respect to the other, stuffing boxes or flexible bulkhead connections are provided—if expansion bends or other offsets are not provided in the piping—to take up the movement. The external surfaces of uncovered and ungalvanized steel or iron piping should be kept properly painted and free of moisture. Copper and brass piping is seldom painted.

Continual LEAKAGE at a JOINT where a branch line joins another line is usually due to improper allowance for expansion in one or the other line, or to excessive vibration. A slight alteration in the anchorages, connections, hangers, or leads of the piping, to allow the required expansion and prevent strain, or the fitting of supports which will prevent vibration, will often correct such leaks. Leaky joints may also be due to poor alinement of the piping, or to movement of decks or bulkheads. Realinements should be made so that flanges or screw threads

meet properly without forcing. Sometimes the flange joints may have to be refaced, or distance pieces fitted. Small leaks in gaskets should be taken up immediately, before a dangerous blowout results from progressive growth of the leak.

PIPE-THREAD LEAKS should be promptly corrected. Leaky screwed joints which cannot be tightened with a reasonable amount of pull-up should be taken apart, cleaned, examined for bad thread conditions, recoated with the appropriate compound, and carefully reassembled, to avoid any other thread damage. Poorly cut threads are a constant source of trouble with threaded pipe joints. The proper use and care of pipe thread cutters will prevent such pipe troubles as shaved thread, wavy thread, and poor shoulders.

PERMANENT OR SEMIPERMANENT REPAIRS of leaky piping sections are generally made by or with the aid of the ship's Pipefitters. Permanent repairs of copper or brass piping may be made by brazing. Small holes may be plugged with a rivet or a screw plug. Semipermanent repairs of leaky piping sections may be made by serving the piping with tightly drawn wire, soldered or brazed as it is applied. Several layers of wire securely bonded give a strong, tight repair.

The life of SALT-WATER PIPING may be lengthened by operating the systems with minimum practical water velocities; by eliminating grounds from electrical systems, especially d-c circuits; by eliminating air from the salt-water systems; by promptly correcting any leaks; by insulating with sheet rubber the hangers which support piping other than that made of wrought iron or steel; and by eliminating wire-drawing, by fully opening valves where throttling is unnecessary.

PIPING INSULATION

Piping insulation represents the composite piping covering which consists of the insulating material,

lagging, and fastening. The INSULATING MATERIAL offers resistance to the flow of heat; the LAGGING, usually of painted canvas, is the protective and confining covering placed over the insulating materials; the FASTENING attaches the insulating material to the piping, and to the lagging.

Insulation Temperature Range

Insulation covers a wide range of temperatures, from the extremely low temperatures of the refrigerating plants, to the very high temperatures of the ship's boilers. No one material could possibly be used to meet all the conditions with the same efficiency. Cork or rock wool, is used for LOW TEMPERATURES. Such basic minerals as asbestos, carbonate of magnesia, diatomaceous earth, aluminum foil, argillaceous (clay-like) limestone, mica, fibrous glass, and diatomaceous silica are employed for HIGH TEMPERATURES. Because of its high degree of refractoriness, diatomaceous silica forms the base of practically every high-temperature insulating material.

Insulating Materials

The following QUALITY REQUIREMENTS for the various insulating materials are taken into consideration by the Navy in the standardization of these materials:

1. Ability to withstand highest or lowest temperature to which it may be subjected without its insulating value being impaired.
2. Sufficient structural strength to withstand handling during its application, and mechanical shocks and vibrations during service, without disintegration, settling, or deformation.
3. Stability in chemical and insulation characteristics.
4. Ease of application and repair.
5. Must not provide a hazard in case of fire.
6. Low heat capacity, when used for boiler wall and furnace insulation, so that starting-up time may be minimized.
7. Must be moisture repellant and vermin proof.

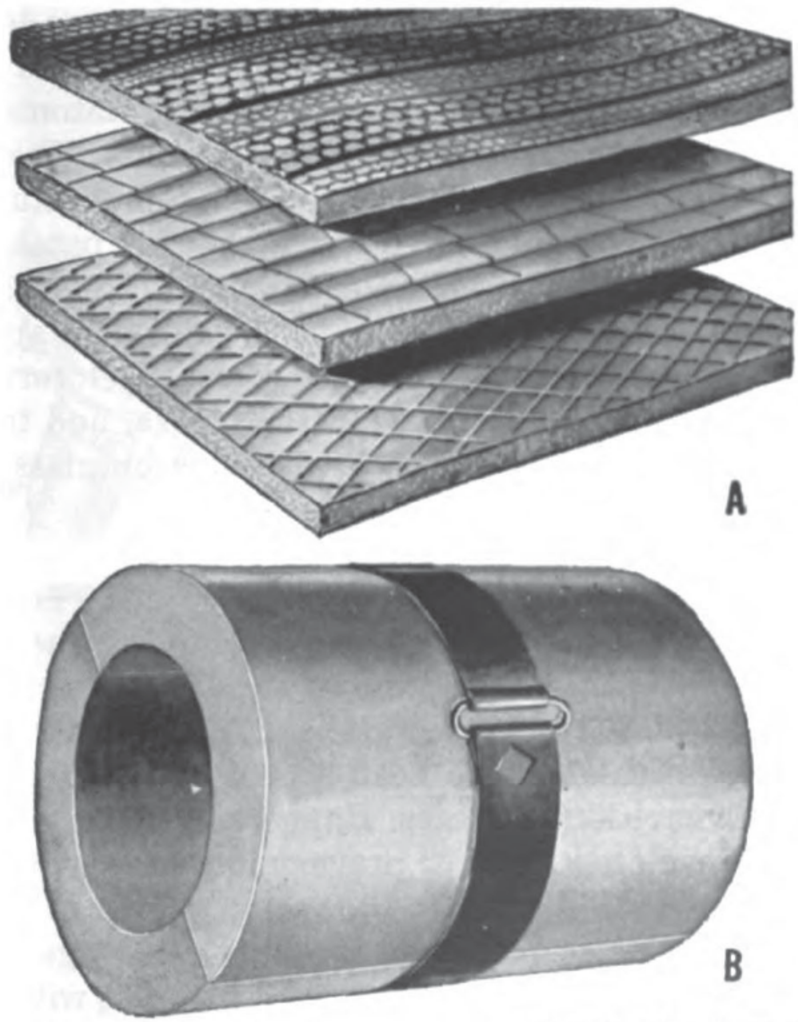
CORK in sheet form is generally limited to refrigeration spaces. MOLDED CORK PIPE COVERING, treated with a fire-retardant compound, is used on refrigerant piping.

MINERAL OR ROCK WOOL is supplied in wire-reinforced pads. This material is suitable for high temperature use, and is particularly useful for insulating large areas (fig. 9–9A).

Molded sheets, pads, blankets, or tapes of long ASBESTOS FIBERS are suitable for insulating temperatures up to 850° F. This insulation material is cheaper and lighter than the diatomaceous earth type, and is durable and rugged. The PADS or BLANKETS are used for insulating flanges or valves which must be taken down fairly often, as well as for turbine casings. The pads are molded to fit any shape, and the outer surface is fitted with metal hooks to facilitate installation and removal. The blankets are made in various thicknesses and widths, and are also fitted with hooks. TAPES are used for covering small piping with curves and bends. They can be used for temperatures up to 750° F, and tend to reduce fire hazards, but have poor insulating quality.

MAGNESIA-ASBESTOS PIPE COVERING (fig. 9–9B) is most commonly used as insulation on high-temperature piping. This material is supplied in molded cylindrical sections which are 3 feet long; each section is split in half lengthwise. Suitable widths are available to fit the various pipe sizes. Magnesia-asbestos pipe covering comes in three grades: Grades I, II, and III are suitable for temperatures up to 500° F, 750° F, and 1050° F respectively.

The DIATOMACEOUS EARTH (formed from skeletons of certain microscopic plants) materials are combinations of the earth and magnesium or calcium carbonates, bonded together with small amounts of asbestos fibers. These materials are heavier, more expensive, and less insulating than others, but their high heat resistance allows their use for temperatures up to 1500° F. When practicable, pipe coverings are made up with this material as an



Courtesy of U. S. Naval Institute

Figure 9–9.—Typical piping insulation materials: (A) mineral wool blankets; (B) magnesia-asbestos pipe covering.

inner layer, and with an outer layer of the magnesia-asbestos material. This lightens the over-all weight.

FIBROUS GLASS SLABS AND BATTS are used widely for insulating hull spaces and living quarters. The fibrous glass has a low moisture absorbing quality, and offers no attraction to insects, vermin, fungus growth, or fire. The slabs are first cut to shape, then secured in place by mechanical fasteners (as quilting pins), and covered with glass cloth facing and stripping tape (held in place by fire-resistant adhesive cement).

The INSULATING CEMENTS are composed of many varied

materials, differing widely among themselves as to heat conductivity, weight, and physical characteristics. Typical of these variations are the asbestos cements, diatomaceous cements, and mineral and slag wool cements. These cements are less efficient than other high-temperature insulating materials, but they are valuable for patch-work emergency repairs, and for covering small irregular surfaces (valves, flanges, joints, etc.). The cements are also used for a surface finish over block or sheet forms of insulation, to seal joints between the blocks, and to provide a smooth finish over which asbestos or glass cloth lagging may be applied (fig. 9–10).

Applying Insulation

Do not allow the insulating materials to become moist. Moisture impairs the insulating value of the material, and may cause eventual disintegration. Large air pockets in the insulation cause large heat losses, so be sure to fill and seal all cavities or cracks. Hangers or other supports should be insulated so as to prevent loss of heat by conduction.

All sections or segments of the pipe coverings should be TIGHTLY BUTTED AT JOINTS, and secured with wire loops, metal bands, or lacing. Block insulation should be secured with 18 gage steel wire and galvanized mesh wire, or expanded metal lattice. Insulating cement should be used to fill all crevices, to smooth all surfaces, and to coat wire netting before final lagging is applied.

MOISTURE PROOFING is just as important in high-temperature insulation as it is in low-temperature insulation. In the former case heat is lost because of evaporation, while in the latter case condensed moisture may freeze. In either case, insulating efficiency is impaired and eventually the insulating material disintegrates.

While the same insulating material employed on the piping may be used, the insulation of pipe fittings, flanges, and valves requires additional consideration. Figure 9–10 illustrates several types of insulation for flanged pipe

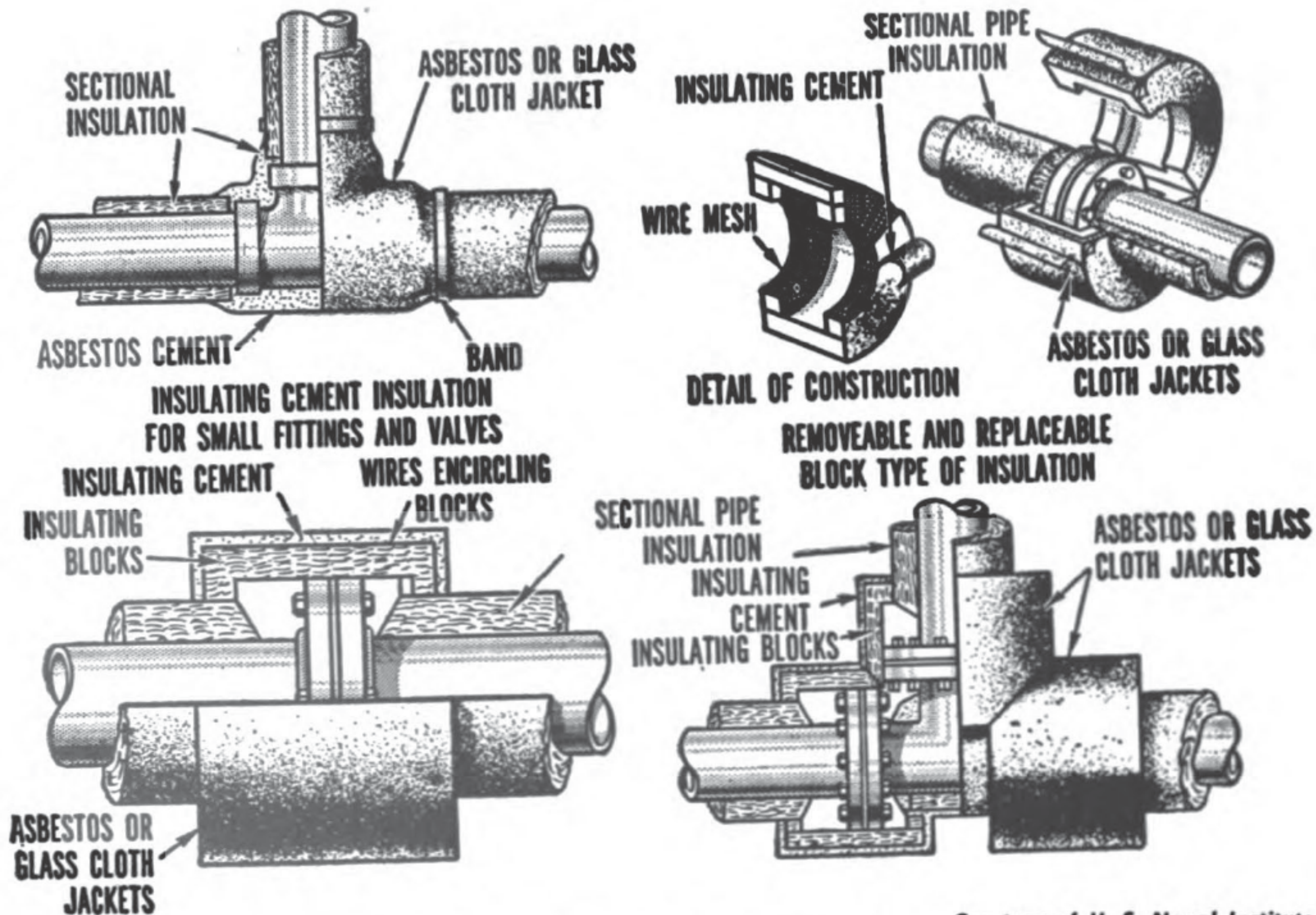


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Figure 9–10.—Permanent type insulation of pipe fittings, flanges, and valves.

joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul.

REMOVABLE TYPE OF INSULATION is usually installed in the following locations:

1. Manhole covers, inspection openings, turbine casing flanges, drain plugs, strainer cleanouts, and spectacle flanges.
2. Flanged pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul.
3. Valve bonnets of valves larger than 2 inches, IPS, that operate at 300 psi and above, or at 240° F and above.
4. All pressure reducing and pressure regulating valves, pump pressure governors, and strainer bonnets.

For a small unit of machinery or equipment such as an auxiliary turbine, where it would be difficult to install both permanent insulation over the casing and removable and replaceable covers over the casing flanges, the entire insulation may be made removable and replaceable. Covers should fit accurately and should project over adjacent permanent insulation.

For piping components any one of the following methods of fabrication is acceptable:

1. Covers may be made in two halves of thermal insulating felt inclosed in asbestos cloth. Each half cover should be sewn and quilted with wire-inserted asbestos yarn, or fastened with mechanical stapling to provide a uniform thickness, strength, and rigidity.
2. Covers for use at temperatures of 850° F and below, should be filled with asbestos felt. Wire-inserted asbestos cloth should be used on the inside surface of the covers.
3. Covers for use at temperatures above 850° F should have filling consisting of inner layers of fiber-glass felt, outer layers of asbestos felt, and should be

covered on the inside surface and on the ends with nickel-chromium alloy wire mesh and on the outside surface with asbestos cloth. Asbestos roll felt, $\frac{1}{8}$ inch thick, should be inserted between the asbestos felt and the asbestos cloth to retain the cylindrical shape of the cover.

For removable and replaceable covers for machinery and equipment, either of the following methods of fabrication is acceptable:

1. Covers may be similar to the flexible asbestos felt or fiber-glass type described for piping components.
2. Covers may be made in sections formed of insulating block and held together with wire and adhesive cement, covered with $\frac{1}{2}$-inch thickness of finishing cement, and lagged. Lacing with hooks, rings, washers, and wire, or brass snap fasteners should be used to secure the covers.

General Insulating Precautions

The following general precautions should be observed with regard to the application and maintenance of insulation:

1. Fill and seal all air pockets and cracks. Failure to do this will cause large losses by conduction, and by convection currents.
2. Seal the ends of the insulation and taper off to a smooth, airtight joint. At joint ends or other points where insulation is liable to damage, use sheet-metal lagging. Flanges and joints should be cuffed with 6-inch lagging.
3. Asbestos cloth covering fitted over insulation should be tight and smooth. It may be sewed with asbestos yarn or may be cemented on.
4. Keep moisture out of all insulation work. Moisture is an enemy of heat insulation fully as much as it is in the case of electrical insulation. Any dampness increases the conductivity of all heat-insulating materials.

5. Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting, otherwise a considerable quantity of heat will be lost via conduction through the support.
6. Sheet-metal covering should be kept bright and not painted unless the protecting surface has been damaged or has worn off. The radiation from bright-bodied and light-colored objects is considerably less than from rough and dark-colored objects.
7. Once installed, heat insulation requires careful inspection, upkeep, and repair. Lagging and insulation removed to make repairs should be replaced just as carefully as when originally installed. When replacing insulation, make certain that the replacement material is of the same type as had been used originally. Old magnesia blocks and sections broken in removal, can be mixed with water and reused in the plastic form for temporary repairs. Save all old magnesia for this use.
8. Insulate all flanges with easily removable forms which can be made up as pads of insulating material wired or bound in place, and the whole covered with sheet-metal casings which are in halves, and easily removable.

The main steam, auxiliary steam, auxiliary exhaust, feed water, and steam heating piping systems are lagged to hold in the heat. The circulating drainage, fire, and sanitary piping systems are lagged to prevent condensation of moisture on the outside of the piping.

PIPING SAFETY PRECAUTIONS

The following safety precautions should be taken whenever you have occasion to work on steam or hot-water lines.

1. To prevent water rams, drain steam piping of water before admitting steam.

2. Before opening large steam valves, open bypasses to warm lines and equalize pressures; if bypasses are lacking, "crack" the valves.
3. Open trap bypasses when admitting steam to piping.
4. When breaking a flange joint, particularly in steam and hot-water lines or in those salt water lines which have a possibility of direct connection with the sea, special precautions should be taken to ensure that:
   (a) there is no pressure on the line;
   (b) the valves cutting pressure off the part of the line undergoing repair are secured in such a manner that they cannot be accidentally opened;
   (c) the line is completely drained; and
   (d) two of the flange-securing nuts (diametrically opposite if possible) remain in place while the others are being removed. The two remaining nuts should then be slacked sufficiently to allow breaking the joint. If the line is clear, all the nuts may be removed. This precaution is necessary to prevent accidents involving scalding personnel or flooding compartments.
5. After remaking a steam joint, tighten up on the nuts according to prescribed methods.
6. Do not use piping for hand or foot holds.
7. Secure copper and brass piping free from contact with bilges. The brackets should be lined with electrical insulating material to prevent direct contact between piping and any of the ship's structure.

TYPES OF VALVES

Valves are usually made of bronze, brass, cast or malleable iron, or steel. Steel valves are either cast or forged, and are made of either plain steel or alloy steel. Alloy steel valves are used in high-pressure, high-temperature systems; the disks and seats of these valves are usually

surfaced with a chromium-cobalt alloy known as STELLITE. This material is extremely hard.

Brass and bronze valves are never used where temperatures exceed 550° F. Steel valves are used for all services above 550° F, and in lower-temperature systems where internal or external conditions of high pressure, vibration, or shock would be too severe for valves made of brass or iron. Bronze valves are used almost exclusively in systems carrying salt water. The seats and disks of these valves are usually made of Monel, a metal which has excellent corrosion- and erosion-resistant qualities.

Many different types of valves are used to control the flow of liquids and gases. As you will remember from your study of *Fireman,* NavPers 10520–A, there are two main groups of valves. STOP VALVES are those which are used to shut off (or, in some cases, to partially shut off) the flow of fluid; these valves are controlled entirely by the movement of the valve stem. CHECK VALVES are used to permit the flow of fluid in only one direction; these valves are controlled by the movement of the fluid itself.

Valve designs vary greatly, due to the diversified demands of service. You will find some valves which are combinations of the more or less basic types just mentioned; and others which must be considered as special valves, bearing only slight resemblance to the basic types. In general, however, we may consider that stop valves include globe valves, gate valves, piston valves, plug valves, and needle valves; and that check valves include swing-check valves and lift-check valves.

Globe Valves

Globe valves are so-called because of the globular shape of their bodies. (It should be noted, however, that other types of valves may also have globe-shaped bodies; hence, the name may tend to be misleading.

In a globe-type stop valve, the disk, which is attached to the valve stem, seats against a seating ring or seating surface and thus shuts off the flow of fluid.

When the disk is raised, fluid can pass through the valve. Globe valves may be used partially open as well as fully open or fully closed.

Globe valve inlet and outlet openings are arranged in several ways, and are used to suit the requirements of flow. Figure 9–11 shows three common types of globe valve bodies. In the straight type, the fluid inlet and outlet openings are in line with each other. In the angle type,

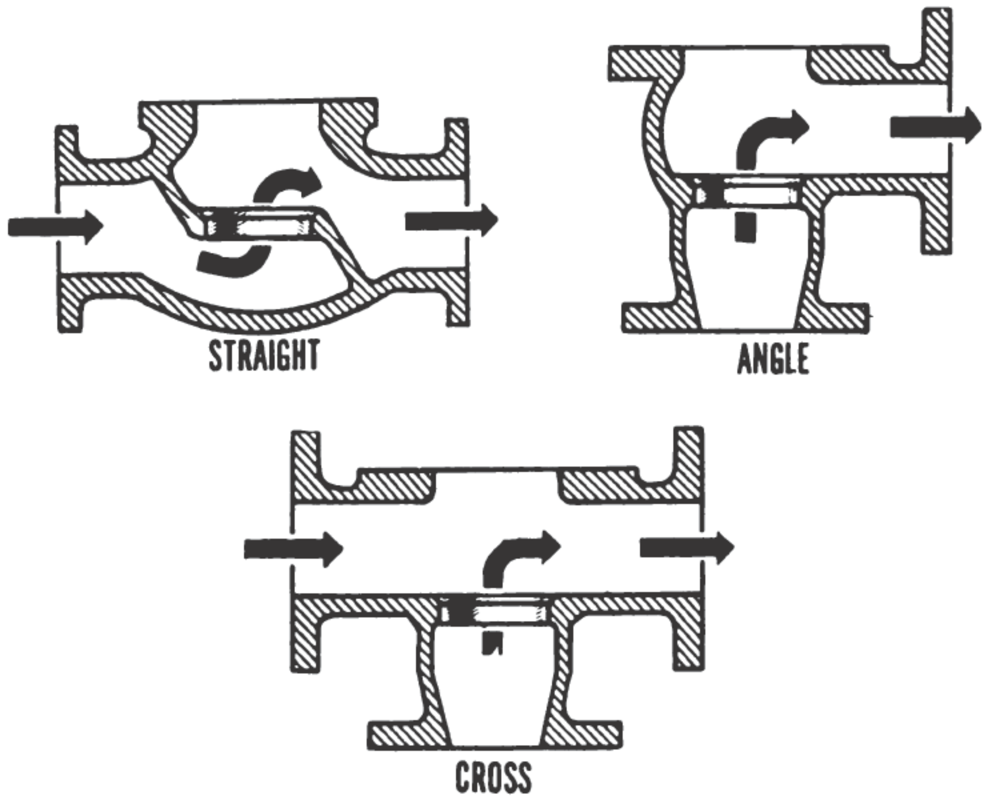

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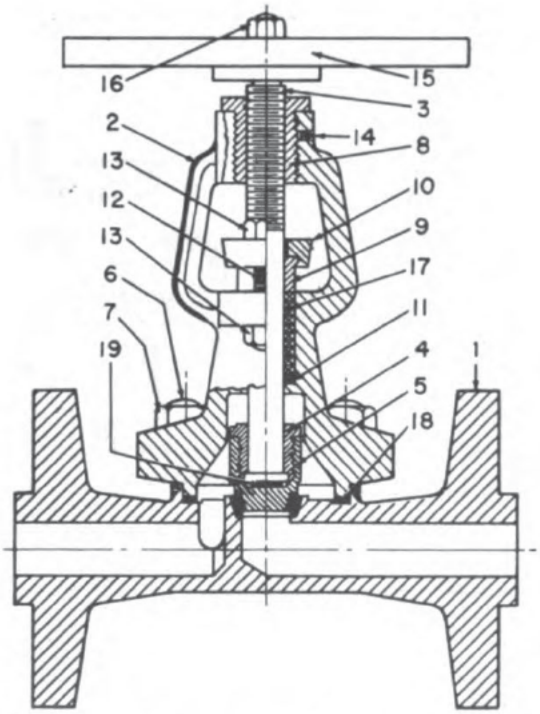
Figure 9–11.—Types of globe valve bodies.

the inlet and outlet openings are at an angle to each other. Angle-type globe valves are most commonly used where it is necessary to make a 90° turn in a line. The cross-type of globe valve has three openings, rather than two; it is frequently used in connection with bypass piping.

A cross-sectional view of a globe stop valve is shown in figure 9–12.

Globe valves may be installed so that the higher pressure is above the disk or below the disk. The method of installation should be governed, in each case, by consideration of the service conditions.



LIST OF PARTS	
PART NO.	NAME OF PART
1	VALVE BODY
2	BONNET
3	STEM
4	DISK NUT
5	DISK
6	BONNET STUD
7	BONNET STUD NUT
8	BONNET BUSHING
9	GLAND
10	GLAND FLANGE
11	PACKING STOP RING
12	GLAND STUD
13	GLAND STUD NUT
14	SET SCREW
15	HANDWHEEL
16	HANDWHEEL NUT
17	PACKING
18	BONNET GASKET
19	DISK WASHER

Figure 9–12.—Cross-sectional view of globe stop valve.

Pressure from BELOW the disk is desirable in cases where the flow must be continuous. For example, a globe valve installed in a boiler feed line should be installed with pressure below the disk, since pressure from above might cause a detached disk to seat and thereby shut off the flow.

The temperature to which the valve will be exposed must also be considered in installing globe valves. If a globe valve for high-temperature service is installed with pressure under the disk, the upper part of the valve is likely to cool when the flow is shut off. Cooling of the stem might cause sufficient contraction to unseat the valve just

enough to cause leakage. The resulting extremely high-velocity flow might cause severe erosion of the disk and seat. In this case, therefore, it would obviously be better to install the valve with pressure from above the disk. Remember that any valve in high-temperature service operates more efficiently if its mechanism is exposed to a constant temperature, and that this condition can be met by installing the valve so that the pressure will be above the disk.

In summary, the general rule for installing globe valves may be stated as follows: always install the valve with pressure ABOVE the disk, unless there is some special reason for installing it with pressure below the disk.

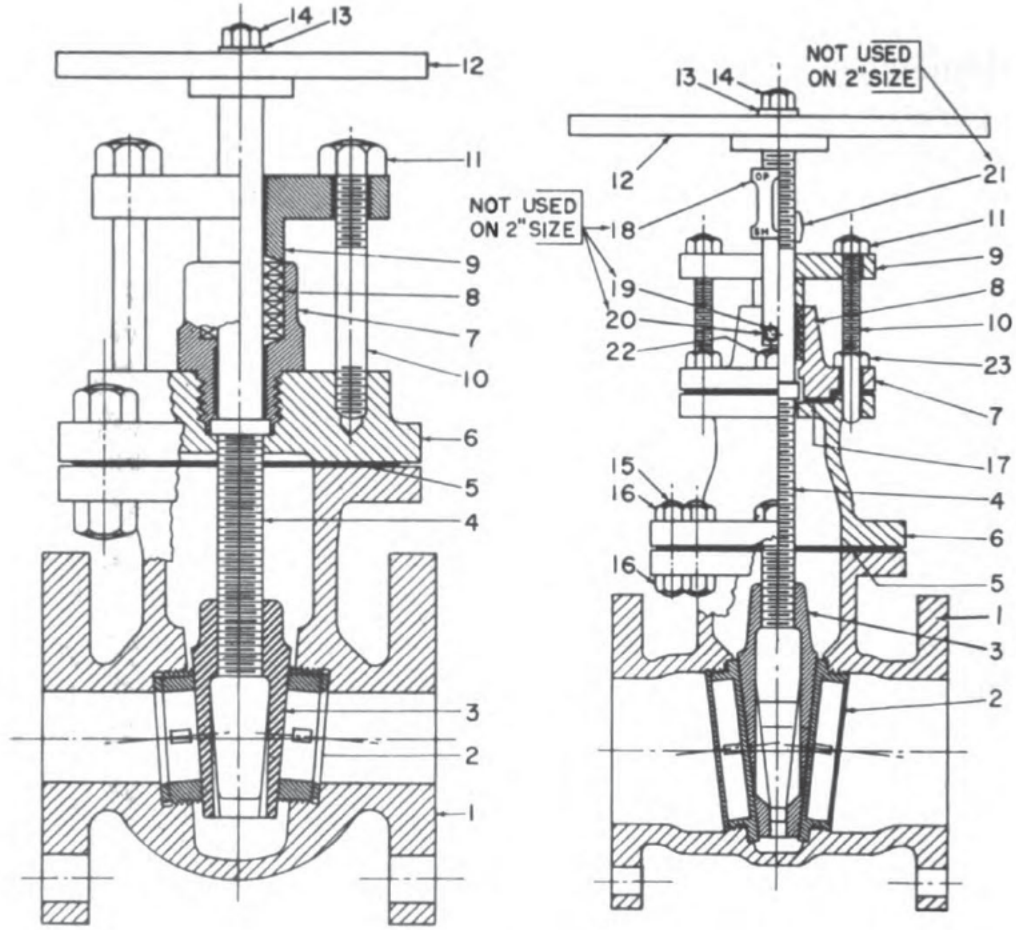
Gate Valves

Gate valves are used when a straight-line flow of fluid is desired. These valves operate on somewhat the same principle as globe valves, but have a wedge-shaped GATE instead of a disk. (The gate is sometimes referred to as a disk, because it serves essentially the same purpose.) When the gate is wide open, the opening through the valve is the same size as the pipe in which the valve is installed; therefore, there is very little resistance to flow and very little pressure drop through this type of valve. Gate valves should NEVER be used as throttling valves, since the flow of fluid against a partially opened gate can cause extensive damage to the valve.

Cross-sectional views of gate stop valves are shown in figure 9–13.

Plug Valves

The body of a plug valve is hollowed out to receive a tapered or cylindrical plug. Holes or ports in the cylinder wall line up with the pipes in which the valve is mounted. A solid cylindrical plug—or, in some cases, a plug shaped like a truncated cone—fits snugly in the hollow cylinder. The plug is attached to a handle, by means of which the plug can be turned within the cylinder. A passage is bored



LIST OF PARTS			
PART NO.	NAME OF PART	PART NO.	NAME OF PART
1	BODY	13	HANDWHEEL WASHER
2	SEAT RING	14	HANDWHEEL NUT
3	GATE	15	BONNET STUD
4	STEM	16	BONNET STUD NUT
5	BONNET GASKET	17	STUFFING BOX GASKET
6	BONNET	18	INDICATOR PLATE
7	STUFFING BOX	19	LOCK WASHER
8	PACKING	20	INDICATOR PLATE SCREW
9	GLAND	21	INDICATOR NUT
10	GLAND STUD	22	STUFFING BOX STUD
11	GLAND STUD NUT	23	STUFFING BOX STUD NUT
12	HANDWHEEL		

Figure 9–13.—Cross-sectional views of gate stop valves.

through the plug. When the valve is in the open position, the passage in the plug lines up with the inlet and outlet ports of the hollow cylinder, and fluid is thus allowed to flow through the valve. When the plug is turned crosswise in the cylinder, the solid part of the plug blocks the ports and stops the flow of fluid.

Three- and four-way cocks which allow selection of the routing of a fluid are usually variations of the plug valve.

Piston Valves

A piston valve is a stop valve which may be thought of as a combination of a gate valve and a plug valve. The piston valve consists essentially of a cylindrical piston operating in a hollow cylinder. The piston is attached to the valve stem, and the valve stem is attached to a handwheel. When the handwheel is turned, the piston is raised or lowered within the hollow cylinder. The hollow cylinder has ports in its wall. When the piston is raised, the ports are uncovered and the fluid is allowed to pass through the valve.

The tightness of this type of valve depends upon the closeness of fit between the piston and the inside of the cylinder. Some piston valves have metal rings on the piston; other types have fiber rings either on the piston or in the wall of the hollow cylinder. The fiber rings can be compressed by means of an external take-up device, so that they expand and thus prevent leakage.

Needle Valves

Needle valves are stop valves that are used for making relatively fine adjustments in the amount of fluid allowed to pass through an opening. A needle valve has a point with a long taper, at the end of the valve stem. This needle acts as a disk. The longer part of the needle is smaller than the orifice in the valve seat, and therefore passes through it before the needle seats. This arrangement permits a very gradual increase or decrease in the

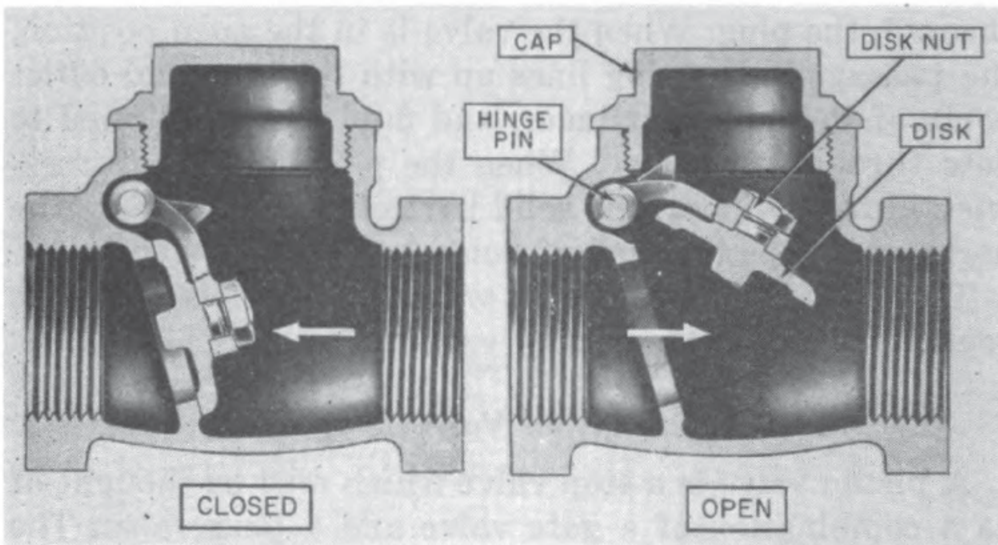


Figure 9–14.—Swing-check valve.

size of the opening, and thus allows more precise control of flow than can be obtained with an ordinary globe valve.

Check Valves

As mentioned before, check valves are used where it is necessary to permit fluid to flow in only one direction. A check valve opens when the pressure on the inlet side is greater than the pressure on the outlet side, and closes when the pressure on the inlet side is less than the pressure on the outlet side. Check valves open and close

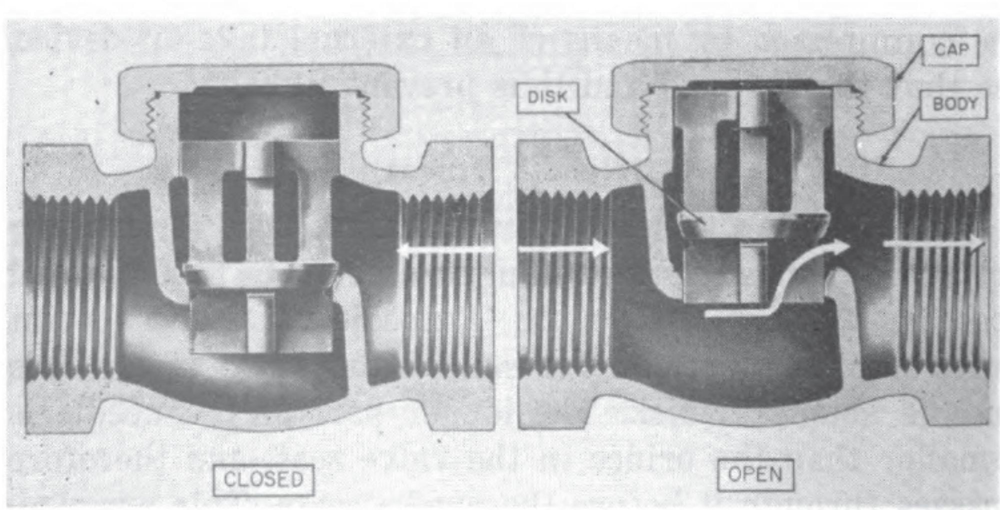
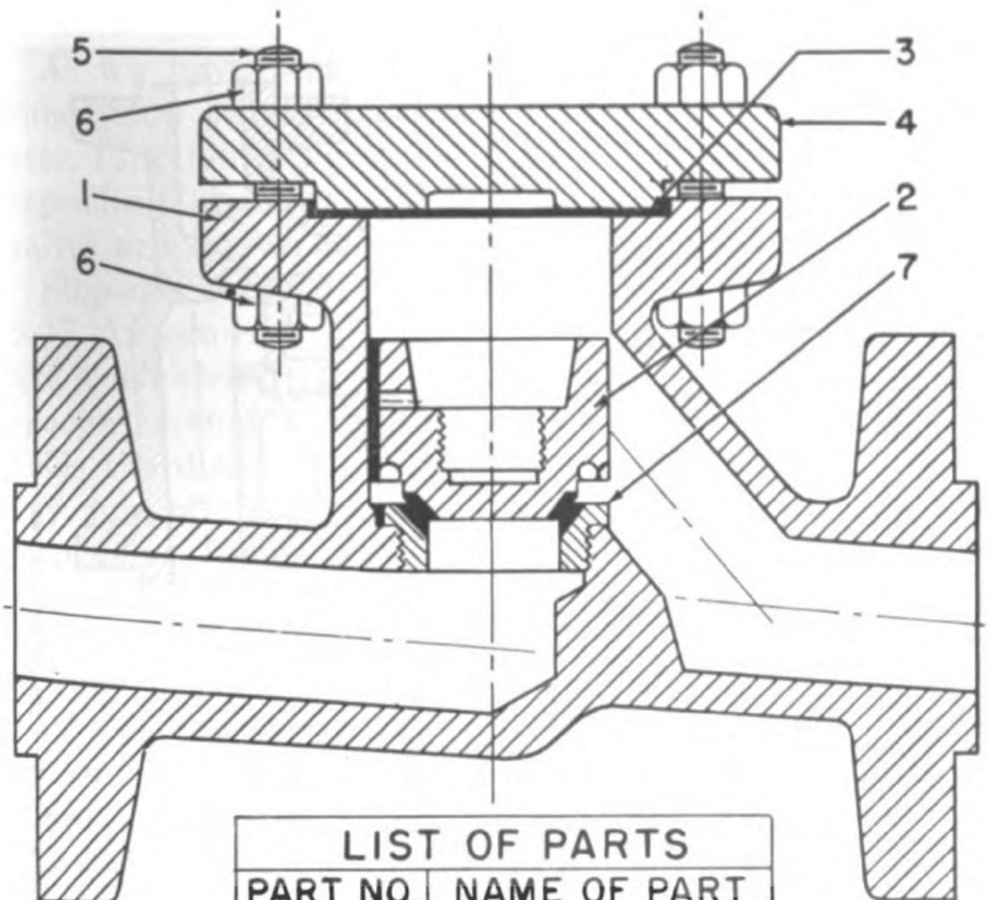


Figure 9–15.—Cutaway view of lift-check valve.

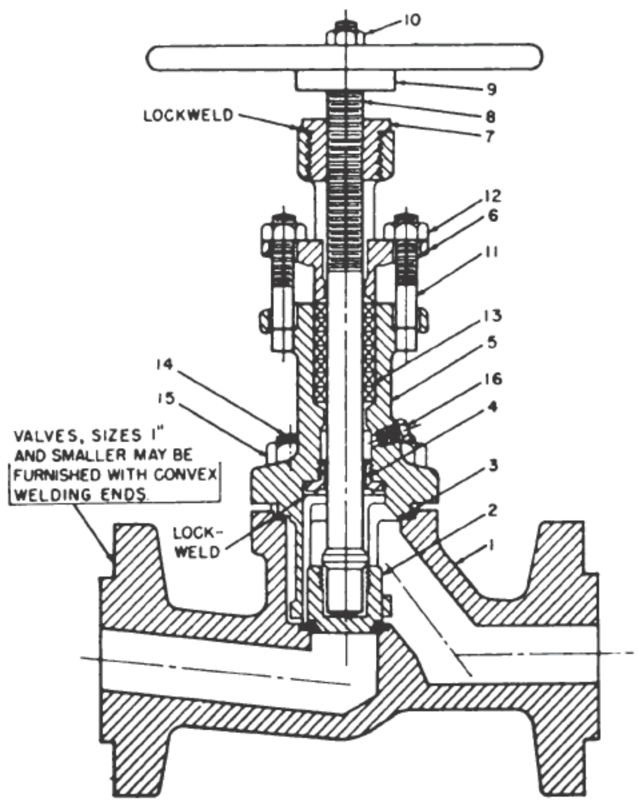


LIST OF PARTS	
PART NO.	NAME OF PART
1	BODY
2	DISK
3	GASKET
4	CAP
5	CAP STUD
6	CAP STUD NUT
7	SEAT RING

Figure 9–16.—Cross-sectional view of lift-check valve.

automatically, but a valve of this type sometimes has a handle or a handwheel which may be used to lock the valve in a closed position or to limit the size of the valve opening.

A disk or a ball is generally used to close the port in a check valve. Figure 9–14 shows the type of valve known as a SWING-CHECK VALVE. Figures 9–15 and 9–16 illustrate the type of valve known as a LIFT-CHECK VALVE.



LIST OF PARTS	
PART NO.	NAME OF PARTS
1	BODY
2	DISK
3	GASKET
4	STEM BUSHING
5	BONNET
6	GLAND
7	YOKE BUSHING
8	STEM
9	HANDWHEEL
10	HANDWHEEL NUT
11	GLAND BOLT
12	GLAND BOLT NUT
13	PACKING
14	BONNET STUD
15	BONNET STUD NUT
16	RELIEF PLUG
17	SEAT RING
18	SPACER
19	GLAND FLANGE
20	YOKE BUSHING SET SCREW
21	JAMB NUT

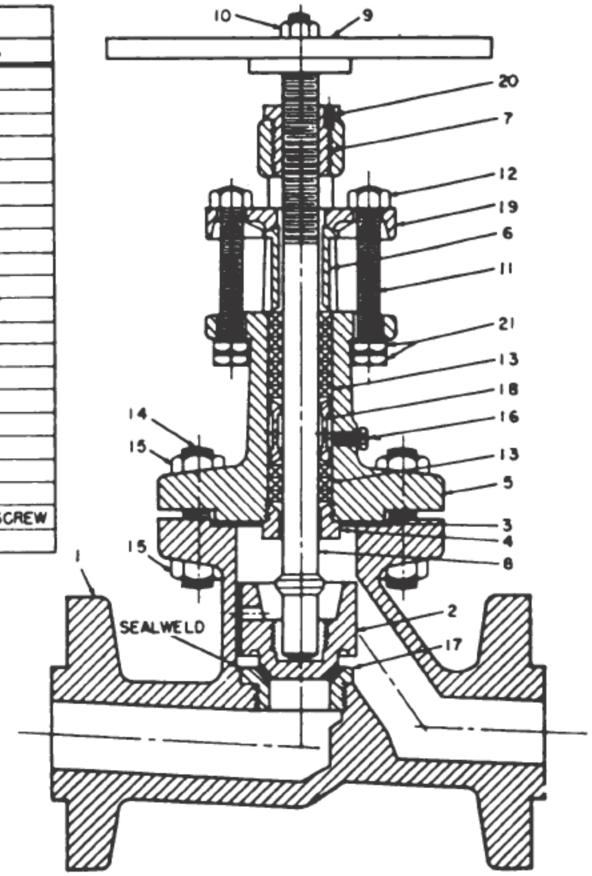


Figure 9–17.—Cross-sectional views of stop-check valves.

Stop-Check Valves

As we have seen, most valves may be classified as either stop valves or check valves. Some valves, however, function either as stop valves or as check valves, depending upon the position of the valve stem. These valves are known as STOP-CHECK VALVES.

Stop-check valves are shown in cross section in figure 9–17. As you can see, this type of valve looks very much like a lift-check valve. However, the valve stem is long enough so that when it is screwed all the way down it holds the disk firmly against the seat, thus preventing any flow of fluid. In this position, the valve acts as a stop valve. When the stem is raised, the disk can be opened by pressure on the inlet side. In this position, the valve acts as a check valve to allow the flow of fluid in only one direction. The amount of the opening is controlled by the position of the valve stem, and the amount of fluid allowed to pass through the valve is thereby regulated.

Another type of stop-check valve is arranged so that the disk may be fully lifted when the valve stem is raised to its highest position. Thus, the valve acts as a stop valve when the stem is all the way down and as a check valve when the stem is partly raised, but allows the free flow of fluid in either direction when the stem is entirely raised.

Throttle Valves for Auxiliary Turbines

Throttle valves provide for quick control in the starting and stopping of a pump turbine, and for regulating the flow of steam to the turbine. A valve of this type requires balancing (especially if manually operated) to remove the strain due to steam pressure under the disk from the valve stem, and to effect a rapid and easy operation. Two principal types of throttle valves are the double-poppet and the balance-piston.

The DOUBLE-POPPET THROTTLE VALVE (fig. 9–18A) consists of two valve disks which are rigidly connected to-

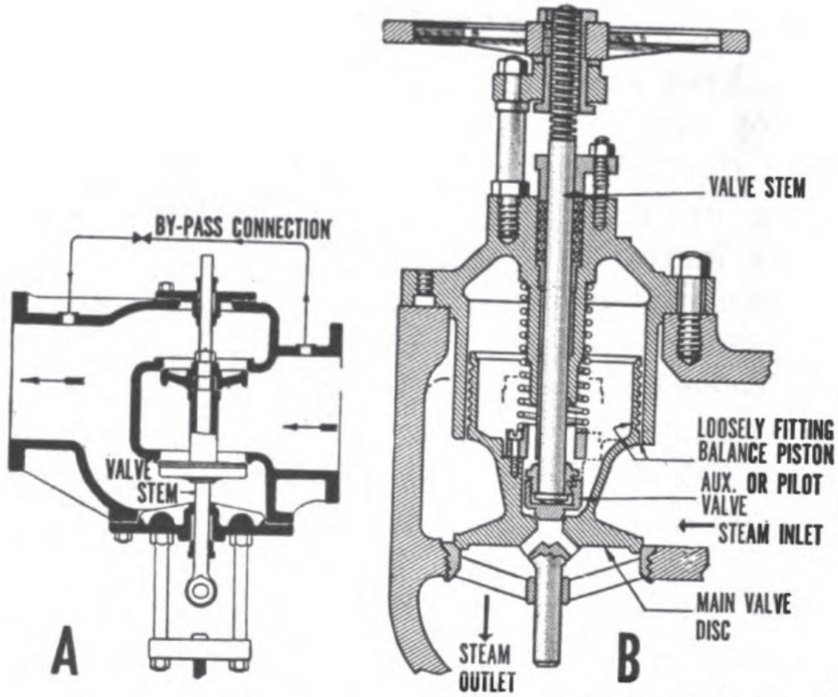


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Figure 9–18.—Throttle valves: (A) double-poppet type, (B) balance-piston type.

gether and fastened to the valve stem with a collar and nut. The lower end of the valve stem is connected to a system of levers which enables the valve to be opened and closed from the engineroom platform. The two valve openings differ slightly in diameter. In the valve illustrated, the orifice at the upper disk is the larger one —affording greater surface for steam pressure, which has a tendency to close the valve.

The inlet steam presses downward on the lower disk and upward on the upper disk which balances the valve and results in the requirement of minimum power to operate it manually. The valve can be quickly opened and closed. A rectangular access in the back of the valve chamber provides for examination of both valve disks. The upper disk can be removed for repairs through this opening; the lower disk can only be removed after the removal of the lower bonnet. A bypass connection, as shown, connects the inlet and outlet chambers of the valve.

The BALANCE-PISTON THROTTLE VALVE (fig. 9–18B) is

designed on the principle of a loose-fitting piston, which is actually a part of the valve disk. In this way, the two double-poppet type parallel valve seats, which are difficult to keep tight, are unnecessary. The piston above the disk is loose fitting, and contains a small pilot valve, attached to the valve stem, which opens in advance of the main valve. In this way the pressure above the piston and below the valve disk is equalized, and an easy opening of the main valve is afforded. The pilot valve also serves as a bypass. A handwheel opens the pilot valve under the stem and relieves the pressure in the space above the piston, balancing the valve in this way. After this, the main valve can be controlled at will.

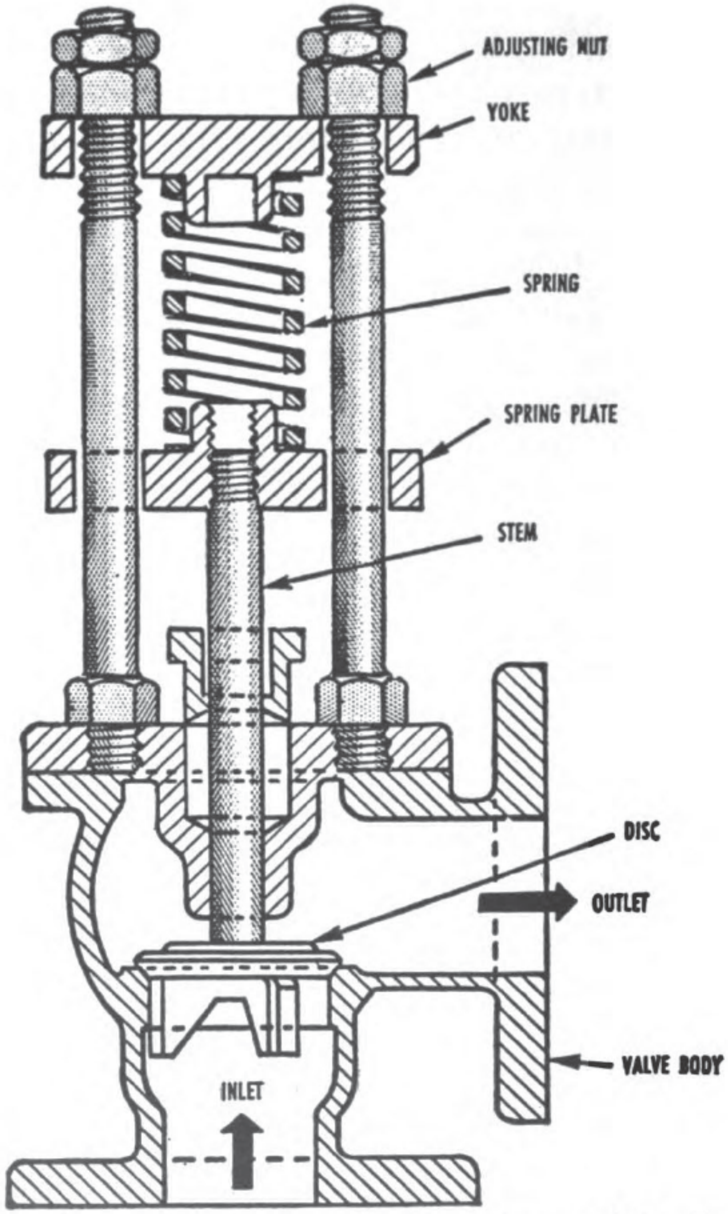
AUTOMATIC THROTTLE VALVES are provided for various types of machinery. With these types, the valve, which is generally operated manually, is released from its manually operated gear, and is closed automatically by an emergency governor. There are many types of these valves, all of which are especially adapted to the machinery of which they are a part.

Pressure Control Valves

There are many types of automatic pressure control valves—some of them merely providing an escape for pressures exceeding the normal pressure; some providing only for the reduction of pressure; and some providing for the regulation of pressure. The valves discussed here are known as relief valves, spring-loaded reducing valves, gas-loaded regulating valves, constant-pressure pump governors, and excess-pressure pump governors.

RELIEF VALVES (fig. 9–19), with which you are probably familiar, are automatic valves used on steam, water, and oil lines, and on various units of machinery. Relief valves prevent the building up of an excessive pressure due to sudden closing of outlet valves, failure of regulating or reducing valves, or other causes.

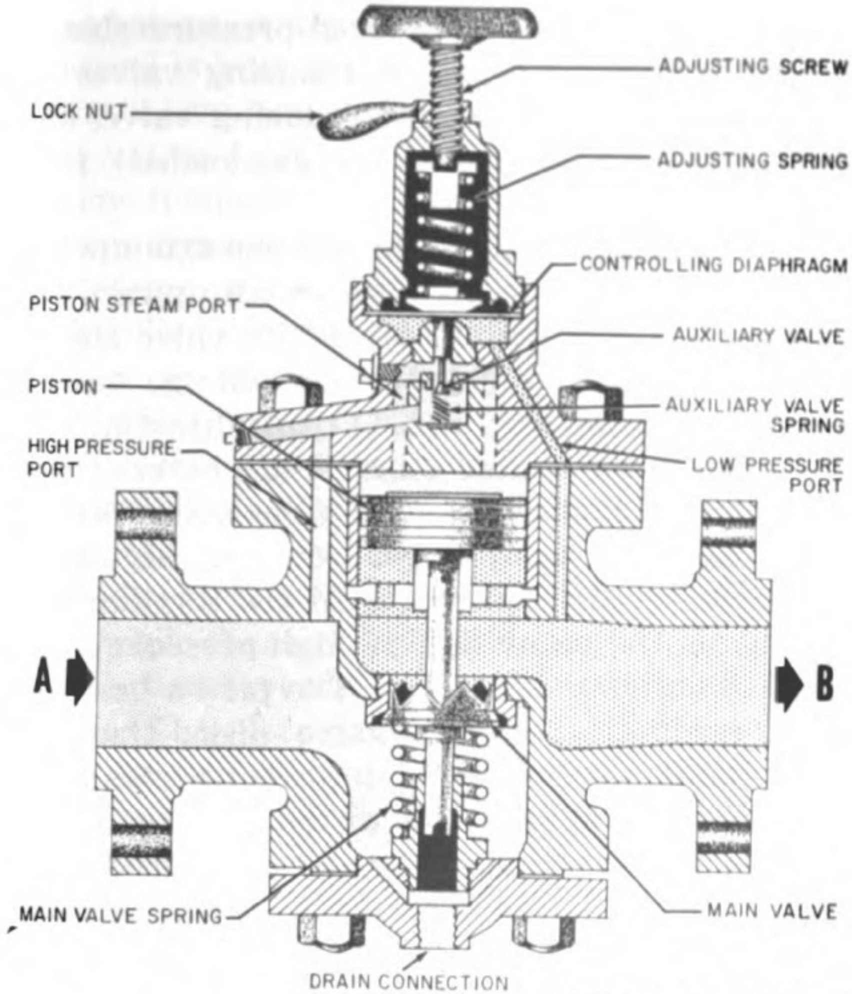
Generally speaking, a relief valve consists of a valve body containing a valve disk, the stem of which extends



Courtesy of U. S. Naval Institute

Figure 9–19.—Relief valve.

into a spring plate. The compression of the heavy spring shown (fig. 9–19) tends to hold the valve down on its seat. The desired setting is attained by manipulation of the adjusting nuts. When the total pressure in the valve inlet exceeds the resistance of the spring on top of the valve, the valve is forced open and the pressure relieved until it falls below that for which the valve is set. Small spring-loaded SENTINEL valves are sometimes attached



Courtesy of U. S. Naval Institute

Figure 9-20.—Spring-loaded reducing valve—showing fluid flow.

to the inlet chamber of relief valves, to give warning of dangerous pressures. Some relief valves have special POPPING or BLOW-DOWN features.

Reducing valves are automatic valves which are used to provide a steady pressure lower than the supply pressure. Reducing valves are used on gland seal lines, galley steam lines, heating steam lines, and on many other reduced-pressure lines. A reducing valve can be set for any desired discharge pressure, within the limits of the design of the valve. After the valve is set, the reduced pressure will be maintained regardless of changes in the supply pressure (as long as the supply pressure is at least as high as the desired delivery pressure) and re-

gardless of the amount of reduced-pressure steam that is used. Two general types of reducing valves are in common use: the spring-loaded reducing valve, and the pneumatic-pressure controlled (or gas-loaded) reducing valve.

The principal parts of a SPRING-LOADED REDUCING VALVE (fig. 9–20) are: (1) the main valve, an upward-seating valve which has a piston on top of its valve stem; (2) an upward-seating auxiliary (or controlling) valve; (3) a controlling diaphragm; and (4) an adjusting spring.

High-pressure steam (or other fluid) enters the valve on the inlet side and acts against the main valve disk, tending to close the main valve. However, high-pressure steam is also led through ports to the auxiliary valve, which controls the admission of high-pressure steam to the top of the main valve piston. The piston has a larger surface area than the main valve disk; therefore, a relatively small amount of high-pressure steam acting on the top of the main valve piston will tend to open the main valve, and so allow steam at reduced pressure to flow out the discharge side.

But what makes the auxiliary valve open to allow high-pressure steam to get to the top of the main valve piston? The controlling diaphragm transmits a pressure downward upon the auxiliary valve stem, and thus tends to open the valve. However, reduced-pressure steam is led back to the chamber beneath the diaphragm; and this steam exerts a pressure upward on the diaphragm, which tends to close the auxiliary valve. The position of the auxiliary valve, therefore, is determined by the position of the controlling diaphragm.

The position of the diaphragm at any given moment is determined by the relative strength of two opposing forces: (1) the downward force exerted by the adjusting spring; and (2) the upward force which is exerted on the under side of the diaphragm by the reduced-pressure steam. These two forces are continually seeking to reach a state of balance; and, because of this, the discharge

pressure of steam is kept constant as long as the amount of steam used is kept within the capacity of the valve.

The PNEUMATIC-PRESSURE CONTROLLED (OR GAS-LOADED) REDUCING VALVE exists in two types—those designed to regulate low-temperature fluids, as air, water, or oil (fig. 9–21A) ; and those designed to regulate high-temperature fluids, as steam or hot water (fig. 9–21B).

Air controlled regulators operate on the principle that the pressure of an enclosed gas varies inversely as its volume. A reduction in volume results in an immediate increase in pressure—and an increase in volume results in an immediate decrease in pressure. A relatively small change in the large volume within the dome loading chamber (fig. 9–21A) produces only a slight pressure variation, while the slightest variation in the small volume within the actuating chamber creates an enormous change in pressure. The restricting orifice connecting these two chambers governs the rate of pressure equalization by retarding the flow of gas from one chamber to the other.

The dome loading chamber is charged with air or other compressible gas at a pressure equal to the desired reduced pressure. When the chamber is loaded, and the loading valve closed, the dome will retain its charge almost indefinitely. In operation the trapped pressure within the dome passes into the actuating chamber through the small separation plate orifice and moves the large flexible diaphragm forcing the reverse acting valve off its seat. The pressure entering the regulator is then permitted to flow through the open valve into the reduced pressure line. A large pressure equalizing orifice transmits this pressure directly to the under side of the diaphragm. When the delivered pressure approximates the loading pressure in the dome, and the unbalanced forces are equalized, the valve is closed. With the slightest drop in delivered pressure, the pressure charge in the dome instantly forces the valve open. This allows air to pass through and thereby maintain the outlet pressure relatively constant.

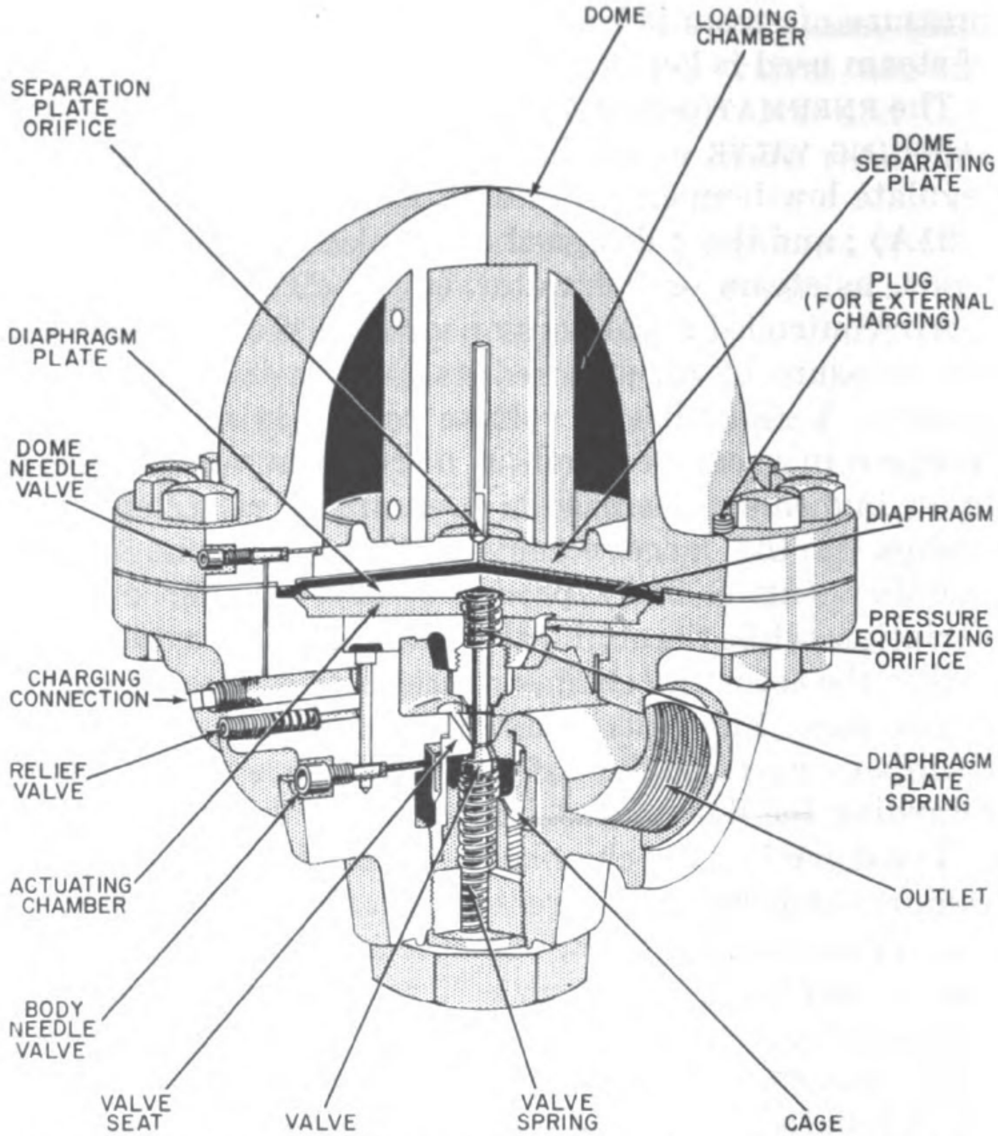


Figure 9–21.—Gas-loaded reducing valve: (A) for low-temperature fluids.

To charge the loading chamber, remove the dome needle valve, connect up the specially furnished hand pump (either 300 or 600 psi) and fill the dome, depending upon the desired outlet pressure. If the regulator is to handle a gas, charge the dome loading chamber with this gas via the dome needle valve and the body needle valve (fig. 9–21A). If the regulator is to handle a liquid, the dome must be charged from an external source. Remove the plug on the dome loading chamber and connect the external source, an air bottle or an air pump. The body

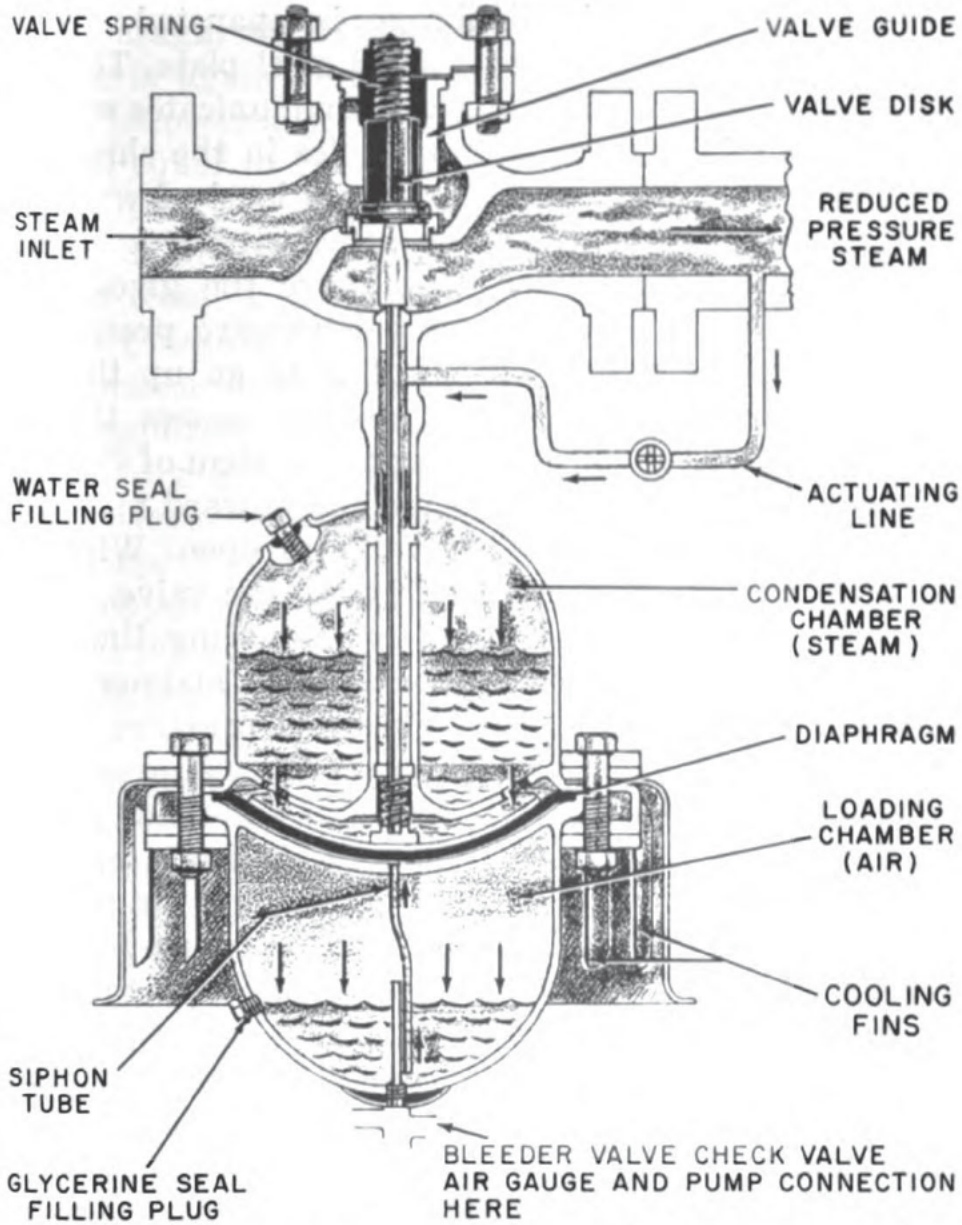


Figure 9–21.—Gas-loaded reducing valve: (B) for high-temperature fluids.

needle valve should be kept closed while the dome needle valve should be used to adjust the dome pressure for obtaining the desired outlet pressure.

Figure 9–21B shows the construction and indicates the operating features of a pneumatic-pressure controlled (or gas-loaded) reducing valve designed to regulate high-temperature fluids.

A rubber diaphragm is installed in the middle of the

dome. The bottom of the diaphragm is separated from the bottom half of the dome by a fixed steel plate. The area immediately above the diaphragm communicates with the upper part of the dome through holes in the shrouding. The upper half of the dome carries a level of water for sealing; the lower half of the dome carries a level of glycerine for sealing. The area above the glycerine is charged with air, which exerts a downward pressure on the glycerine and forces some of it to go up the tube toward the diaphragm. This pressure causes the diaphragm to move upward; and, since the stem of the valve is in contact with the diaphragm, the upward movement of the diaphragm causes the valve to open. When the valve is open, steam can pass through the valve.

From the outlet connection, an actuating line leads back to the upper part of the dome, in the manner shown in figure 9–21B. Steam at the reduced pressure is thus allowed to exert a force on the top of the water seal; this force is transmitted through the water and tends to move the diaphragm downward. When the pressure or steam from the actuating line exceeds the loading air pressure in the lower half of the dome, the diaphragm moves downward sufficiently to close the valve. The closing of the valve reduces the pressure of the steam on the discharge side of the valve. When the pressure on the outlet side of the valve is equal to the air pressure in the lower half of the dome, the valve takes a balanced position which allows the passage of sufficient steam to maintain that pressure.

If the steam load increases, tending to take more steam away from the valve, the outlet pressure will be momentarily reduced. Thus, the pressure of steam on top of the diaphragm becomes less than the pressure of air below the diaphragm, and the valve then opens wider to restore the outlet pressure to normal. If the demand is reduced, this causes a momentary increase in outlet pressure, and this in turn increases the pressure on top of the diaphragm above that of the air pressure below it, causing

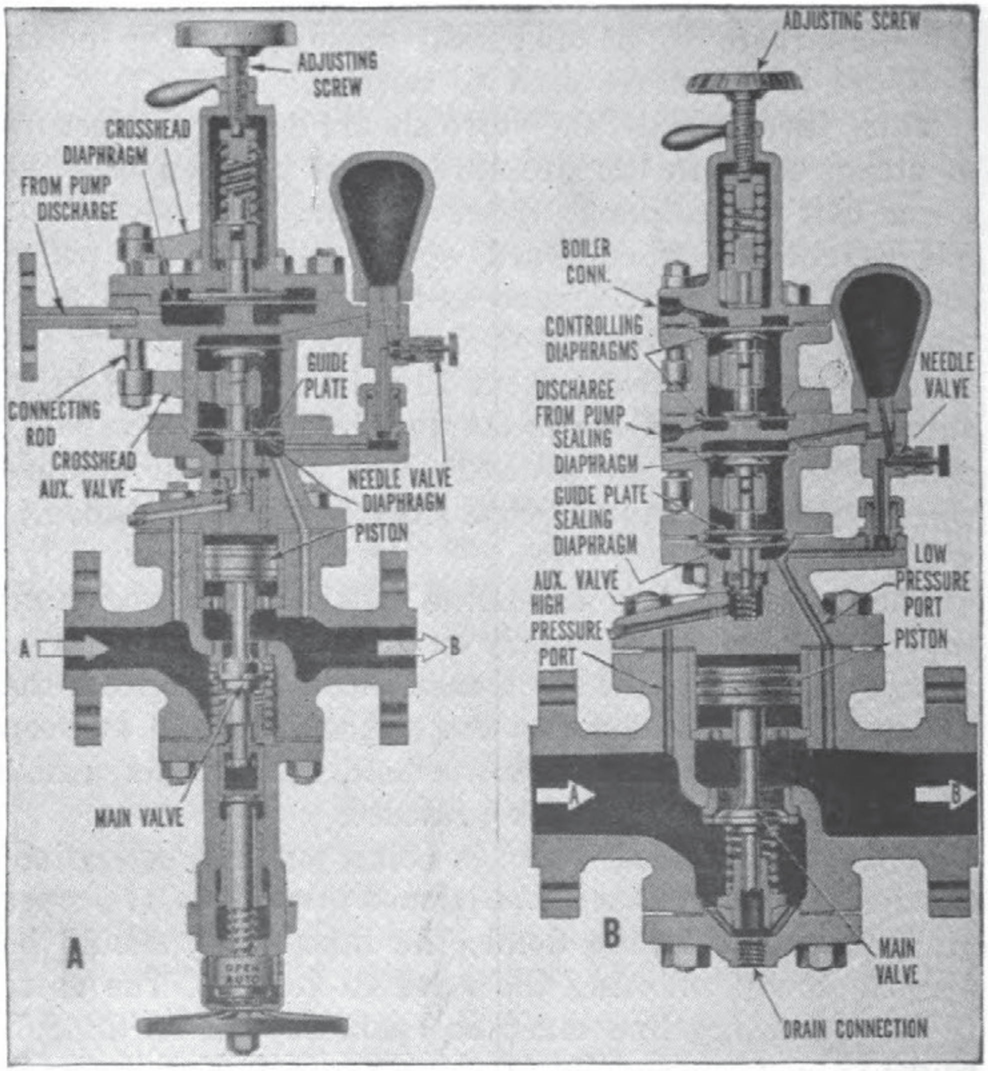
the diaphragm to be displaced downward. The outlet pressure is again restored to normal.

Thus, theoretically, the valve should deliver a pressure of steam equal to the pressure of air pumped into the lower half of the dome. However, since the valve itself has weight and is equipped with a light spring which tends to close it, it is necessary to introduce slightly more air pressure than is theoretically required. For the higher pressure valves, about 10 psi additional air pressure is required. If air is pumped in when the valve is cold, slightly less air pressure will be needed because the air pressure will increase slightly when the valve is warmed up.

The copper shroud extending outside the dome from the center flange appears only on the high-pressure valves. It is installed to allow for transmission of heat from the upper half of the dome to the atmosphere and to keep heat from passing into the lower half, where it may cause an excessive rise in the air pressure.

When the reducing valve is being put into operation, the discharge valve should be opened first. Then, if proper air pressure is in the dome, the inlet valve should be opened slowly, allowing the valve to heat up. The valve in the actuating line must be open. It will be difficult to get these valves on the line unless some steam is being bled away from the discharge. It is desirable to have some steam leaving the valve when cutting it in. If you are careful to warm up reducing valves properly and to put them on the line slowly, no trouble should be encountered with their operation. Glycerine should always be used for the lower seal. Water should be used for the upper seal; the condensation of steam in the upper part of the dome is usually sufficient to maintain the water seal at the proper level.

The CONSTANT-PRESSURE PUMP GOVERNOR (fig. 9–22A) is a modification of the spring-loaded reducing valve. This governor so regulates the steam supplied to the steam turbine or piston, that the driven pump will dis-



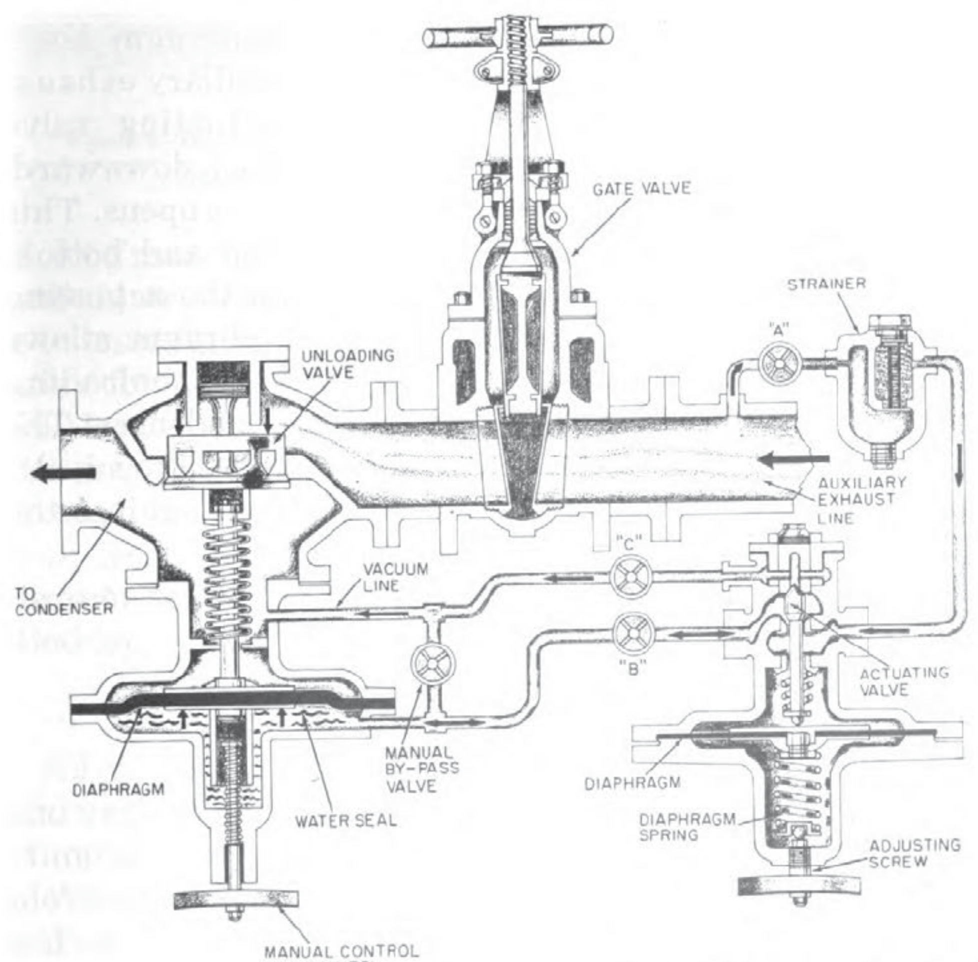
Courtesy of U. S. Naval Institute

Figure 9–22.—Pump governor valves: (A) constant-pressure governor, (B) excess-pressure governor.

charge its fluid at a constant pressure. The reducing valve, on the other hand, maintains a constant reduced pressure on the discharge side of its line. The design of the governor (fig. 9–22A) differs from that of the reducing valve (fig. 9–20) in that, instead of the underside of the controlling diaphragm being exposed to the outlet reduced pressure, it is connected to a line leading from the pump discharge. The diaphragm is thus exposed to the pump discharge pressure, which the governor maintains at a

specific constant level. A drop or rise in the pump discharge pressure will actuate the governor, in somewhat the same manner that a change in the reduced pressure actuates the spring-loaded reducing valve. A succession of openings and closings (needle valve, auxiliary valve, etc.) within the regulator allows for the time lag of the pump turbine in its responding to the changes in steam supply through the governor.

The EXCESS-PRESSURE PUMP GOVERNOR (fig. 9–22B), sometimes used for feed-water pump control, is employed where a fixed pressure differential is required between the discharge pressure of the pump, and the pressure of the unit (boiler) fed by the pump.



Courtesy of U. S. Naval Institute

Figure 9–23.—Automatic unloading valve.

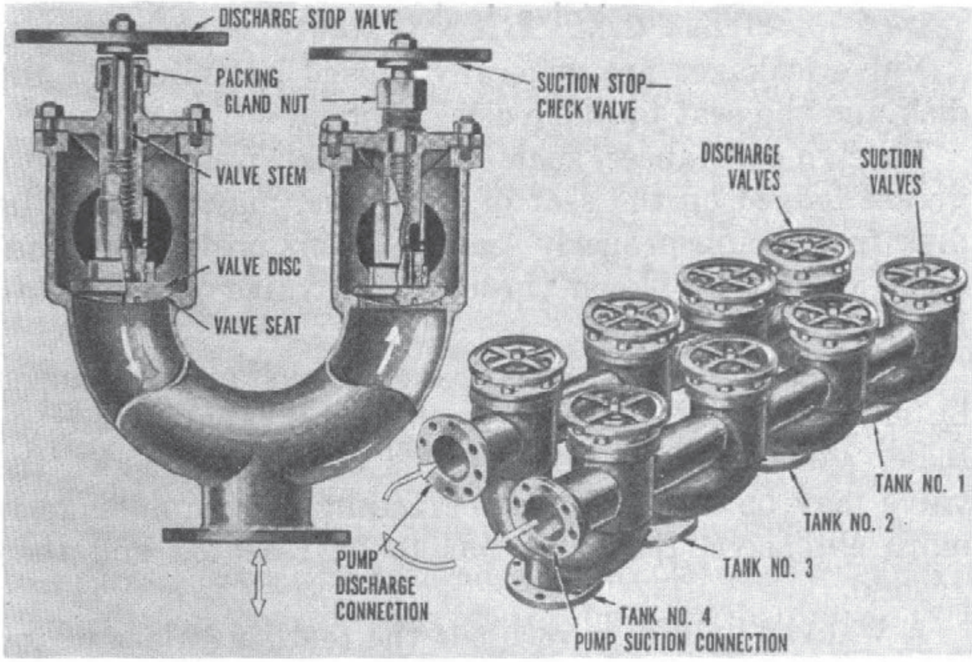
An AUTOMATIC UNLOADING VALVE (fig. 9–23) or "dumping valve," is installed at each main and auxiliary condenser. The function of these valves is to discharge steam from the auxiliary exhaust line into the condensers whenever the exhaust line pressure exceeds a certain amount, usually 18 psi.

In figure 9–23, auxiliary exhaust steam is led through valve *A* to the top of the actuating valve diaphragm. The actuating valve is double-seated, and one side is open while the other is closed. When the auxiliary exhaust line pressure is less than the preset pressure, the upper seat is closed and the lower seat is open. The valve is thus held by the diaphragm spring. Steam passes into the line through valve *B* and under the unloading valve diaphragm. The pressure acting on this diaphragm holds the unloading valve up and closed. If the auxiliary exhaust pressure exceeds the pressure of the actuating valve diaphragm spring, the diaphragm is forced downward, and the lower seat closes while the upper seat opens. This makes a direct connection between the top and bottom of the unloading valve diaphragm through the actuating valve. The equalized pressure on the diaphragm allows the auxiliary exhaust pressure to force the unloading valve down and steam is unloaded to the condenser. The unloading pressure can be adjusted by turning the adjusting screw and thereby changing the tension against the actuating valve diaphragm.

To operate the valve manually, it is necessary to open the bypass valve. This equalizes the pressure on both sides of the unloading valve diaphragm.

Valve Manifolds

Sometimes it is necessary to take suction from any one of many sources, and discharge to another unit or units of either the same or another group. A valve manifold is used for this type of operation. An example of such a manifold (fig. 9–24) is the fuel-oil filling and transfer system, where provision must be made for the transfer



Courtesy of U. S. Naval Institute

Figure 9–24.—Valve manifold showing cutaway view of the valves and typical combination of suction and discharge valves.

of oil from any tank to any other tank, to the service system, or to another ship. If, for example, the purpose is to transfer oil from tank No. 1 to tank No. 4, the filling valve for tank No. 4 and the discharge valve from tank No. 1 are opened, and all other valves closed. Fuel-oil can now flow from tank No. 1, through the suction line, through the pump, through the discharge valve, and into tank No. 4. The manifold filling valves are often of the stop-check type, to prevent draining of pumps when they are stopped.

VALVE MAINTENANCE

All valves require proper care and maintenance, just as do all larger units of equipment, if they are to be kept in optimum working order. The principal difficulties encountered with valves are leakages past the seat and disk, leakages at the stuffing box, sticking valve stems, loose valve disks, etc. You should know how to prevent and correct these faults.

Valve Leakages

Valve leakages are generally caused by failure of the disk and the seat to make close contact.

Foreign substances, such as scale, dirt, waste, or heavy grease lodged on the seat of the valve, may prevent the disk from being properly seated. If this obstructing material cannot be blown through, the valve will have to be opened and cleaned.

SCORING of the valve seat or disk, which may be caused by erosion or by attempts to close the valve on dirt or scale, will result in leaks. If this damage is slight, the valve may be made tight by grinding. If the damage is more extensive, the valve has to be reseated and then ground.

A WARPED DISK may result if the feather guides fit too tightly, if the spindle guide is bent, or if the valve stem is bent. This, too, will cause a valve to leak or will destroy the tightness of a valve. Or the valve disk or body may be too weak for the purpose used, thus permitting distortion of the disk or seat under pressure.

Leakages around THREADS OF SEAT RINGS in bronze valves will result in leakages through the valve. To correct this, remove the seat ring, clean the threads, and remake the joint. Sometimes it is necessary to recut the threads in the valve and to replace the seat ring with a new one.

The USE OF WRENCHES to close valves tightly is not advisable, because valves are frequently sprung out of shape in this way. If a valve leaks or the stem sticks, the packing gland should be eased up so that the valve will close tightly without the use of a wrench.

LOSSES DUE TO LEAKS which are not corrected mount up considerably, over a period of time. Wire drawing and erosion cause the degree of leakage to increase. A small $1/32''$ hole, for example, would waste, over a period of a month, 69,552 cubic feet of air at 100 psi, 3175 pounds of steam at 100 psi, or 4800 gallons of water at 40 psi.

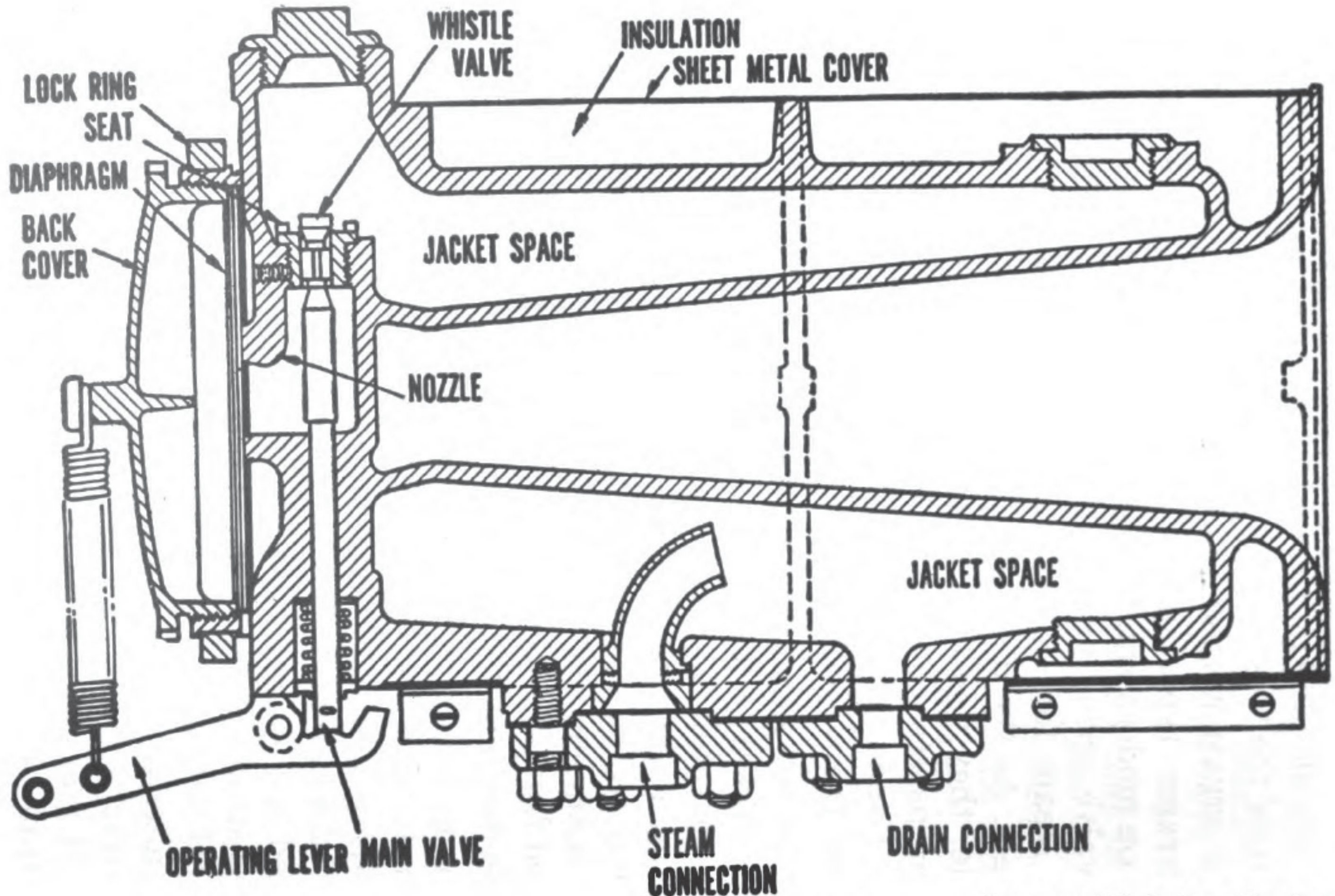
STEAM WHISTLES AND SIRENS

Since you will have to maintain, and occasionally repair, the steam whistles and sirens installed on your ship, you should know something about their construction and how they work.

The STEAM WHISTLE illustrated in figure 9–25 is of the diaphragm type, and is typical of the steam whistles used on modern ships. When the operating lever is pulled, the valve opens and admits steam through the orifice. This steam forces the spring-metal diaphragm disks to the left. As the disks attempt to spring back against the nozzle, they vibrate and produce an audible sound. The steam passes out around the nozzle and through the horn. Condensate leaks off through the drain connection. Before the whistle is used, the drain should be opened.

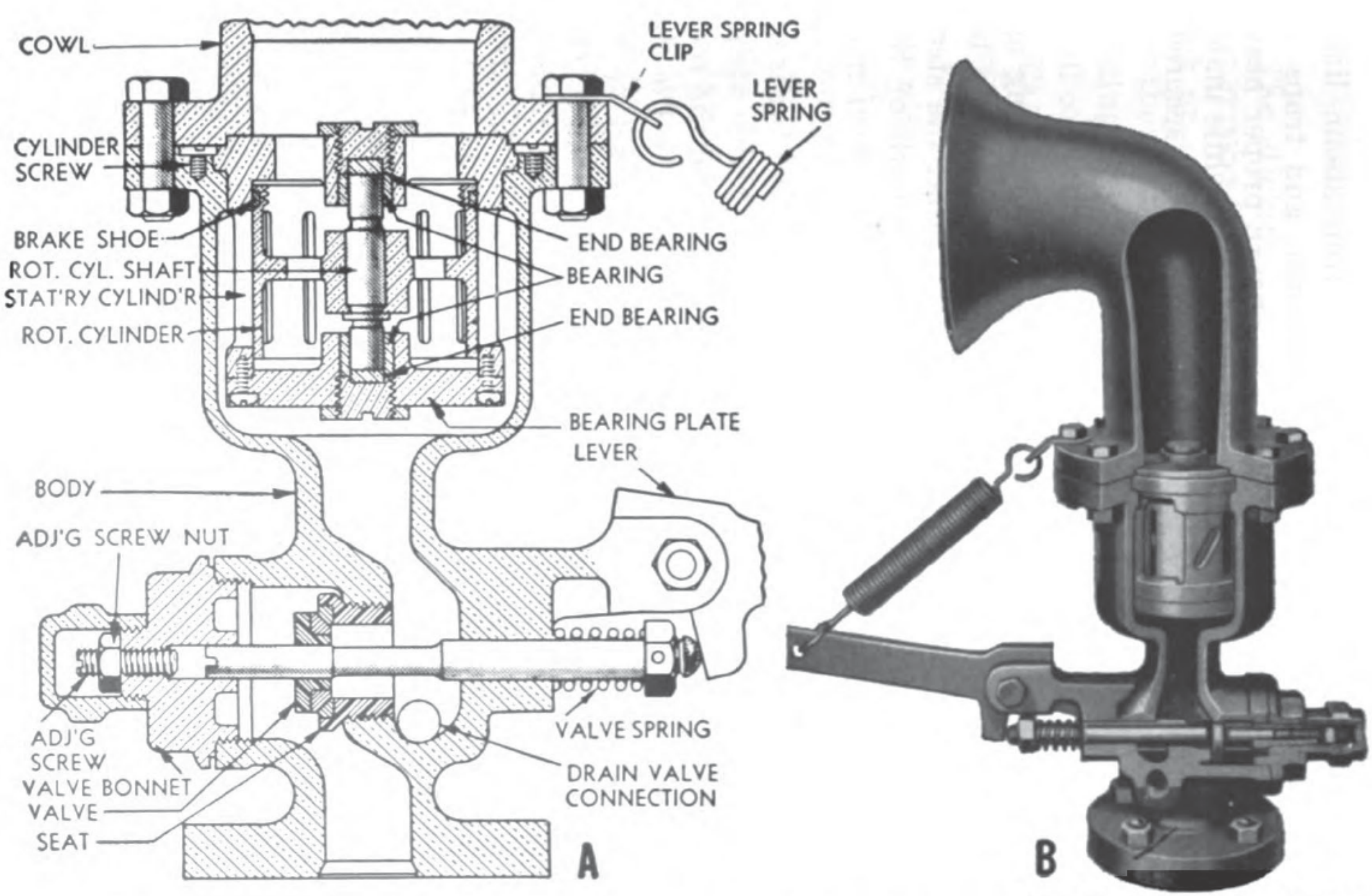
To ensure against damage, a steam separator (located below decks) is installed in the steam line to the whistle. The separator removes condensate from the steam by imparting a whirling motion to the steam when it passes on its way to the whistle. The whirling motion is set up by stationary curved baffles and guide vanes. Water is removed from the steam by the centrifugal motion imparted to the steam by the baffles and guide vanes.

Steam enters the STEAM SIREN (fig. 9–26) through a control valve and fills an annular chamber which surrounds a stationary slotted cylinder. This cylinder is pierced by a series of beveled slots. Inside is a second slotted hollow cylinder. The slots of the fixed cylinder act as steam nozzles which direct steam against the rotating cylinder's vertical slots which act as turbine blades. The alternate covering and uncovering of the slots, as the rotor speeds up with pressure of the steam, sets up violent vibrations of increasing frequency in the column of steam escaping through the megaphone above the cylinder. The speed of the inner cylinder rotation determines the pitch of the sound. Brake shoes, attached to the rotating cylinder, prevent overspeeding.



Courtesy of U. S. Naval Institute

Figure 9–25.—Sectional view of a typical steam whistle (diaphragm type)



Courtesy of U. S. Naval Institute

Figure 9–26.—Steam siren: (A) sectional view, (B) exterior view.

When a ship is in port, the steam lines to the whistle and siren should be secured. About an hour prior to getting under way, the whistle and siren steam lines should be turned on with all drains open and traps in operation for at least 30 minutes to ensure proper heating and removal of condensate. AT NO TIME, while under way, should the whistle and siren steam lines be secured.

STUFFING BOX LEAKAGES

STUFFING BOX LEAKS CAN BE REMEDIED by setting up on the gland, or by repacking it. The gland must not be set up on nor packed so tightly, however, that the stem binds. If the leaks persist after either or both of the remedies are applied, a bent or scored valve stem may be the cause.

In REPACKING THE STUFFING BOXES, successive turns of the packing material are placed around the valve stem. Where string packing is used, it is coiled around the rod. The ends are beveled off to make a smooth seating for the bottom of the gland, which is then put on and set up by the bonnet nut, or the gland bolts and nuts. To prevent the STRING PACKING from folding back when the gland is tightened down, the packing should be wound in the same direction as the gland nut is turned. Leakages are less likely this way, because there are no joints in the packing. Where SUCCESSIVE RINGS are used, the ends of the packing rings should be cut square and even, and the ends butted to make a level joint. The different rings should break joints. If rings are put in place with PACKING STICKS, care should be taken not to break the packing.

In some gate, globe, angle, and stop-check valves, the STUFFING BOXES MAY BE REPACKED UNDER PRESSURE, when necessary. These valves are so constructed that the stem is back-seated against the bonnet, when the valve is wide open. High-pressure valves are provided with a pressure leak-off connection. This pressure leak-off connection is sealed to the outside with a pipe plug. Extreme care

should be taken that the valve is firmly back-seated before the plug is removed.

Sticking Valve Stems

The sticking of valve stems may be caused by the STUFFING BOX being set up on or packed too tightly. Slacking up on the gland will relieve this packing pressure. Or the stuffing box gland may be warped, due to uneven setting up on the gland nuts. Balancing these settings will correct this latter condition.

PAINT OR RUST on the valve stem should be removed by cleaning the stem.

JAMMING THE VALVE SHUT WHILE IT IS COLD results in the disk being bound tightly to the seat because of the expansion caused by the subsequent heating. To relieve this strain, carefully slack off the yoke nuts; if it is not a yoke valve, slack back slightly on the bonnet nuts. The disk can then generally be freed from the seat.

JAMMING THE VALVE OPEN WHILE IT IS HOT may result in the valve being bound open, due to subsequent contraction. With this condition, the valve can usually be started toward the closed position with a wrench, though care must be taken not to spring the valve stem. If, after opening a valve wide, you turn the stem a half revolution in the closing direction, the danger of valve binding due to expansion will be eliminated.

The valve may become stuck if the VALVE STEM THREADS are burred from rough handling, or upset from pressure which has been applied to move sticking valves. This is a serious valve trouble. If the valve can't be moved by any other method, the bonnet must be removed, the stem cut out of the yoke or bonnet, and a new stem made. If the bonnet and yoke are damaged, they must be repaired. If the burred or upset threads are detected before the stem becomes stuck, they can be dressed smooth with a file, or machined in a lathe.

If the sticking is due to a BENT VALVE STEM, the stem must be either straightened or renewed.

All important valves, and all other valves liable to stick, should be operated once a month or oftener, to prevent or discover any sticking condition.

Loose Valve Disks

If a valve disk comes loose from its stem, it is due either to FAILURE OF THE SECURING DEVICE or to corrosion through the stem. The first cause does not often occur in valves of good construction. Any recurrence of this cause can be prevented by minor adjustments, or by taking greater care in the reassembly of valve parts.

Trouble due to CORROSION THROUGH THE STEM occurs mostly in valves installed in salt-water lines. The stems of these valves should be periodically inspected, so that replacements can be made before any valve failure occurs. In making replacements of parts, the disks, disk nuts, split-pins in the disks, and seat rings should be of nickel-copper alloy, instead of iron or steel; the stems should be of rolled Monel metal.

VALVE REPAIR

The information on valve repair which is given in this section refers primarily to globe valves and gate valves. Plug valves usually require lathe work when they become leaky. Piston valves may require the renewal of packing or rings. The other types of valves previously discussed may be repaired in much the same manner as globe and gate valves, with appropriate modifications as necessary.

Valve repair (other than routine packing) is generally limited to overhaul of the seat and the disk. However, all other parts of the valve must be inspected and, if found to be defective, must be repaired or replaced. The valve seat and the valve disk should be closely inspected for evidence of erosion, cuts on the seating area, and improper fit of the disk to the seat. If the disk and the seat appear to be in good condition, they should be spotted-in to determine whether they actually seat properly. You

should know how to repair defective valves. You should also know how to install, reface, grind, spot in, and (where necessary) lubricate valves.

Spotting-In

The method used to determine visually whether or not the seat and the disk make good contact with each other is called SPOTTING-IN. To spot-in a valve seat, first apply a thin coating of prussian blue evenly over the entire machined face surface of the disk. Then insert the disk into the valve and rotate it a quarter turn, using a light downward pressure. The prussian blue will adhere to the valve seat at points where the disk makes contact. Figure 9–27 shows what a correct seat looks like when it is spotted-in, and also shows what various kinds of imperfect seats look like.

After you have noted the condition of the seat surface, wipe all the prussian blue off the disk face surface. Apply

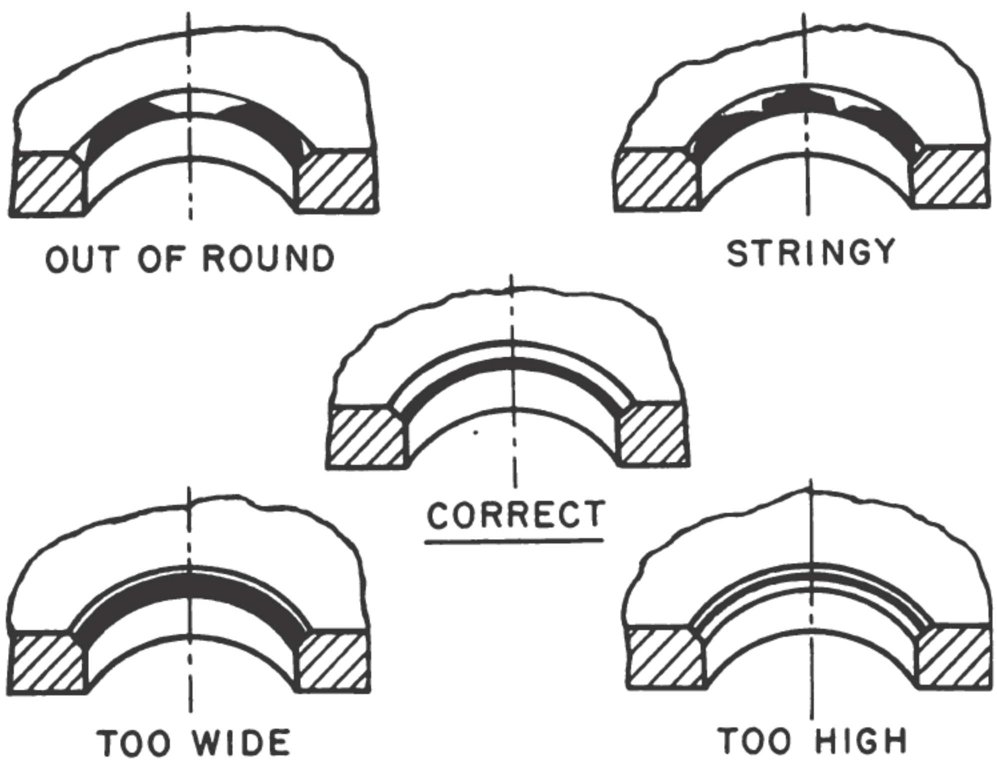


Figure 9–27.—Correct seat and various imperfect seats.

a thin, even coat of prussian blue to the contact face of the seat, and again place the disk on the valve seat and rotate the disk a quarter of a turn. Examine the resulting blue ring on the valve disk. The ring should be unbroken and of uniform width. If the blue ring is broken in any way, the disk is not making a proper fit.

Grinding

A large number of naval vessels are provided with power driven valve grinding machines. These machines were originally designed for hard-faced (Stellite) valves. It has been found that the machines are also suitable for use on a large number of valves that have soft metal seats.

Before you use the reseating machines, study the manufacturer's instruction manual for the valve reseating machine that you are using.

In the event that the machines are not available or do not fit a particular malfunctioning valve, the following procedure is prescribed:

To grind-in a valve, apply a small amount of grinding compound to the face of the disk. Insert the disk into the valve and rotate the disk back and forth about a quarter of a turn, shifting the disk-seat relation from time to time so that the disk will be moved gradually, in increments, through several rotations. During the grinding process, the grinding compound will gradually be displaced from between the seat and disk surfaces; therefore, it is necessary to stop every minute or so to replenish the compound. When you do this, you should wipe both the seat and the disk clean before applying the new compound to the disk face.

When it appears that the irregularities have been removed, spot-in the disk to the seat, in the manner previously described.

Grinding is also used to follow up all machining work on valve seats or disks. When the valve seat and disk are first spotted-in after they have been machined, the seat contact will be very narrow and will be located close to

the bore. Grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring, covering approximately one-third of the seating surface.

Be careful that you do not overgrind a valve seat or disk. Overgrinding tends to produce a groove in the seating surface of the disk, and also tends to round off the straight, angular surfaces of the disk. Machining is the only process by which overgrinding can be corrected.

Lapping

A cast iron LAPPING TOOL, or LAP, of exactly the same size and shape as the valve disk, is used to true the valve seat surface. A lapping tool is shown in figure 9–28. THE VALVE DISK MUST NEVER BE USED AS A LAP.

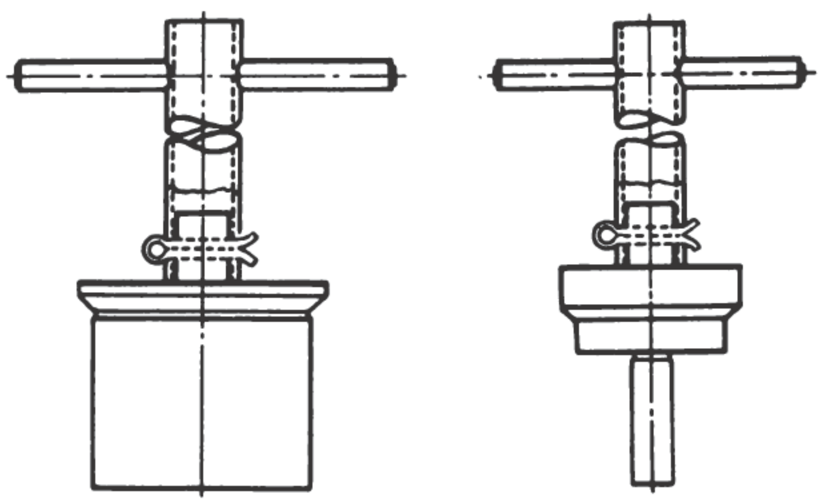


Figure 9–28.—Lapping tool.

Lapping allows you to remove slightly larger irregularities from the valve seat than can be removed by grinding. The most important points to remember while using the lapping tool are as follows:

1. Do not bear heavily on the handle of the lap.
2. Do not bear sideways on the handle of the lap.
3. Change the relationship between the lap and the valve seat so that the lap will gradually and slowly rotate around the entire seat circle.

4. Keep a check on the working surface of the lap. If a groove develops, have the lap refaced.
5. Always use clean compound for lapping.
6. Replace the compound often.
7. Spread the compound evenly and lightly.
8. Do not lap more than is necessary to produce a smooth and even seat.
9. Always use a fine grinding compound to finish the lapping job.
10. Upon completion of the lapping job, spot-in and grind-in the disk to the seat.

Lapping is the best method for correcting gate valve defects such as light pitting or scoring, and imperfect seat contact. The lapping process is the same for gate valves as it is for globe valves, except that the lap is turned by a handle which extends through the end of the valve body. The lapping tool, without its handle, is inserted into the valve in such a manner that it covers one of the seat rings. Then the handle is attached to the lap and the lapping is begun. The wedge gate can be lapped to a true surface, using the same lap that is used on the seat rings. CAUTION: Do NOT use the gate as a lap.

Lapping and Grinding Compounds

Only approved abrasives should be used for reconditioning valve seats and disks. The current specification for lapping and grinding compound is Fed. SS–C–614, Type I. This compound is supplied in six grades, four of which are suitable for lapping and grinding valve disks and seats. The coarse grade is used when extensive corrosion or deep cuts and scratches are found on the disks and seats. The medium grade is used to follow up the coarse grade, and may also be used to start the reconditioning process on valves which are not too severely damaged. The fine grade should be used when the reconditioning process nears completion. The microscopic fine grade is used for finish lapping, and for all grinding-in.

Refacing

Badly scored valve seats or disks have to be refaced either in a lathe or in a reseating machine. Scored, high-pressure steam line valves should be refaced on a lathe because the valve is Stellite-faced.

To reface a composition valve seat (bronze, etc.), attach the correct 45° facing cutter to the HAND RESEATING TOOL (fig. 9–29). With a fine file, remove all high spots on the surface of the flange (sometimes inside the valve opening and sometimes around the surface of the opening) upon which the chuck jaws are to fit. The valve must have the inside of the bonnet flange bored true with the

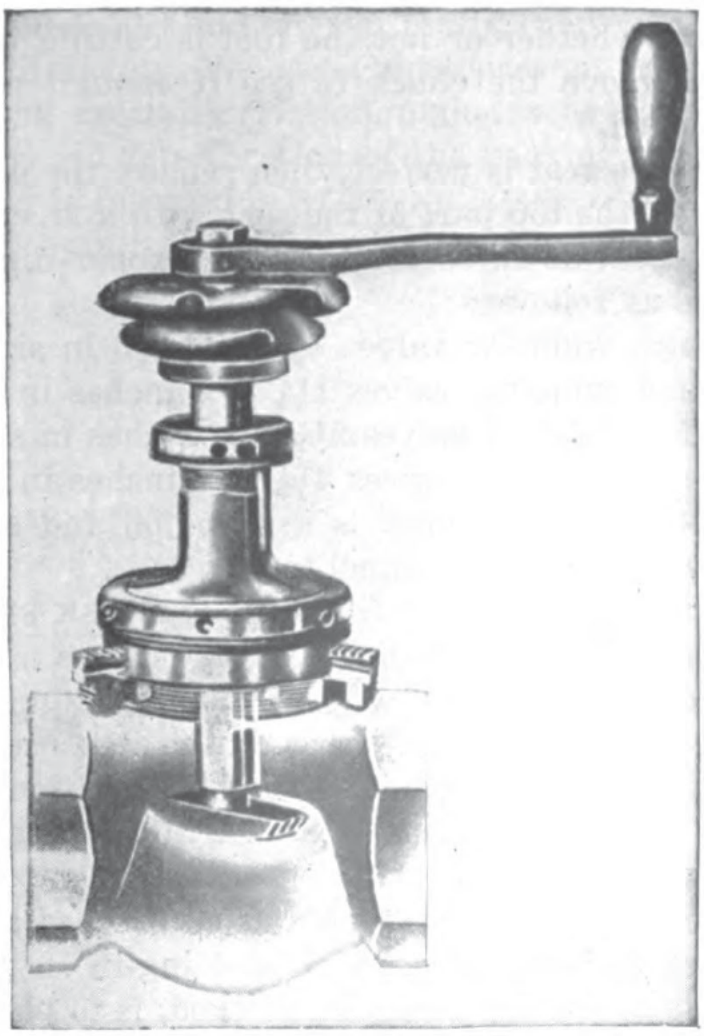


Figure 9–29.—Hand reseating tool showing valve seat being refaced.

valve seat before the reseating machine can be used. If this condition does not exist, the valve must be reseated in a lathe, and the inside flange bored true.

Before placing the chuck in the valve opening, open the jaws of the chuck wide enough to rest on the flange of the opening. Now tighten up on the jaws lightly so that the chuck securely grips the sides of the valve opening, tap the chuck down with a wooden mallet until the jaws rest firmly and squarely on the flange, and then tighten up further on the jaws.

Adjust and lock the machine spindle in the cutting position and start the cutting by turning slowly on the crank. Feed the cutter slowly so that very light shavings are taken. After some experience, you will be able to know by the feel whether or not the tool is cutting evenly all around. Remove the chuck to see if enough metal has been removed.

Be sure the seat is perfect, then remove the 45° cutter and face off the top part of the seat with a FLAT CUTTER. Dress the seat down carefully to the proper dimensions, which are as follows:

$\frac{1}{16}$ inch wide for valves $\frac{1}{4}$ to 1 inch in size.
$\frac{3}{32}$ inch wide for valves $1\frac{1}{4}$ to 2 inches in size.
$\frac{1}{8}$ inch wide for valves $2\frac{1}{2}$ to 4 inches in size.
$\frac{3}{16}$ inch wide for valves $4\frac{1}{2}$ to 6 inches in size.

REMACHINING THE DISK is a shop job and should be turned over to shop personnel to do.

Following the refacing, the SEAT AND DISK SHOULD BE GROUND TOGETHER with an abrasive, such as a grinding compound, powdered emery, or ground glass mixed with oil. Turn the disk back and forth on the seat, occasionally lifting it from the seat and shifting its position slightly. Continue the grinding until a bearing is obtained all around.

As a test of the refacing operation, proceed according to the instructions given under spotting-in on page 341. An alternative, though a rough method, is to place pencil marks at intervals of about $\frac{1}{2}$ inch on the bearing surface

of the seat or disk. Place the disk on the seat and rotate it about a quarter of a turn. If all pencil marks rub off, the seating is satisfactory.

PACKING

There are many different kinds of packing that are used to seal machinery joints against leaks. As a Machinist's Mate, you will be concerned primarily with the packing of moving and fixed joints.

Packing of Movable Joints

The packing of moving joints: sliding (pistons, piston rods, and expansion joints), rotating (shafts), and those operating helically and intermittently (valve stems), offer the most difficulty. The seals must prevent leakage without causing excessive friction, undue wear of the moving part, or rapid deterioration of the packing.

Packing is inserted in STUFFING BOXES (fig. 9–30) that consist of annular chambers located around valve stems,

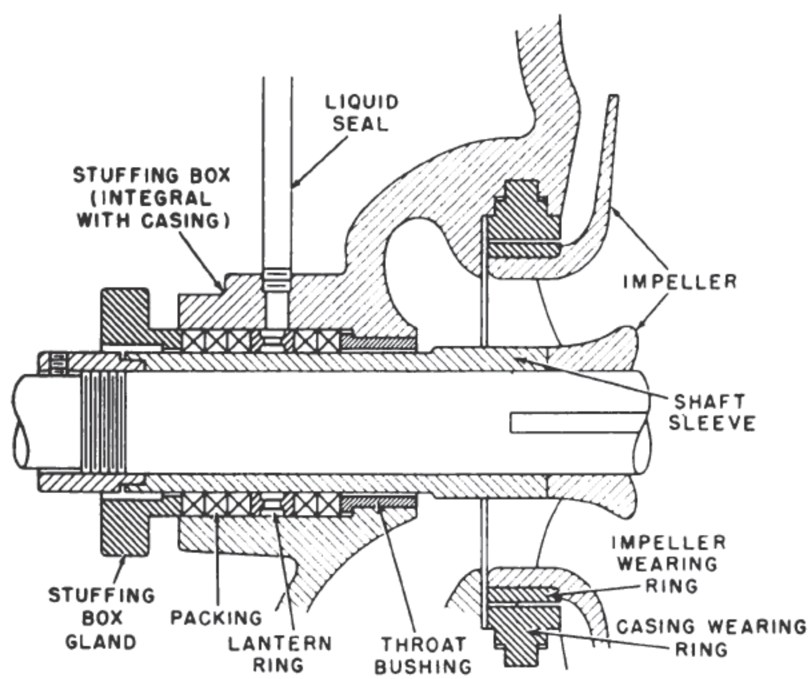


Figure 9–30.—Stuffing box on centrifugal pump.

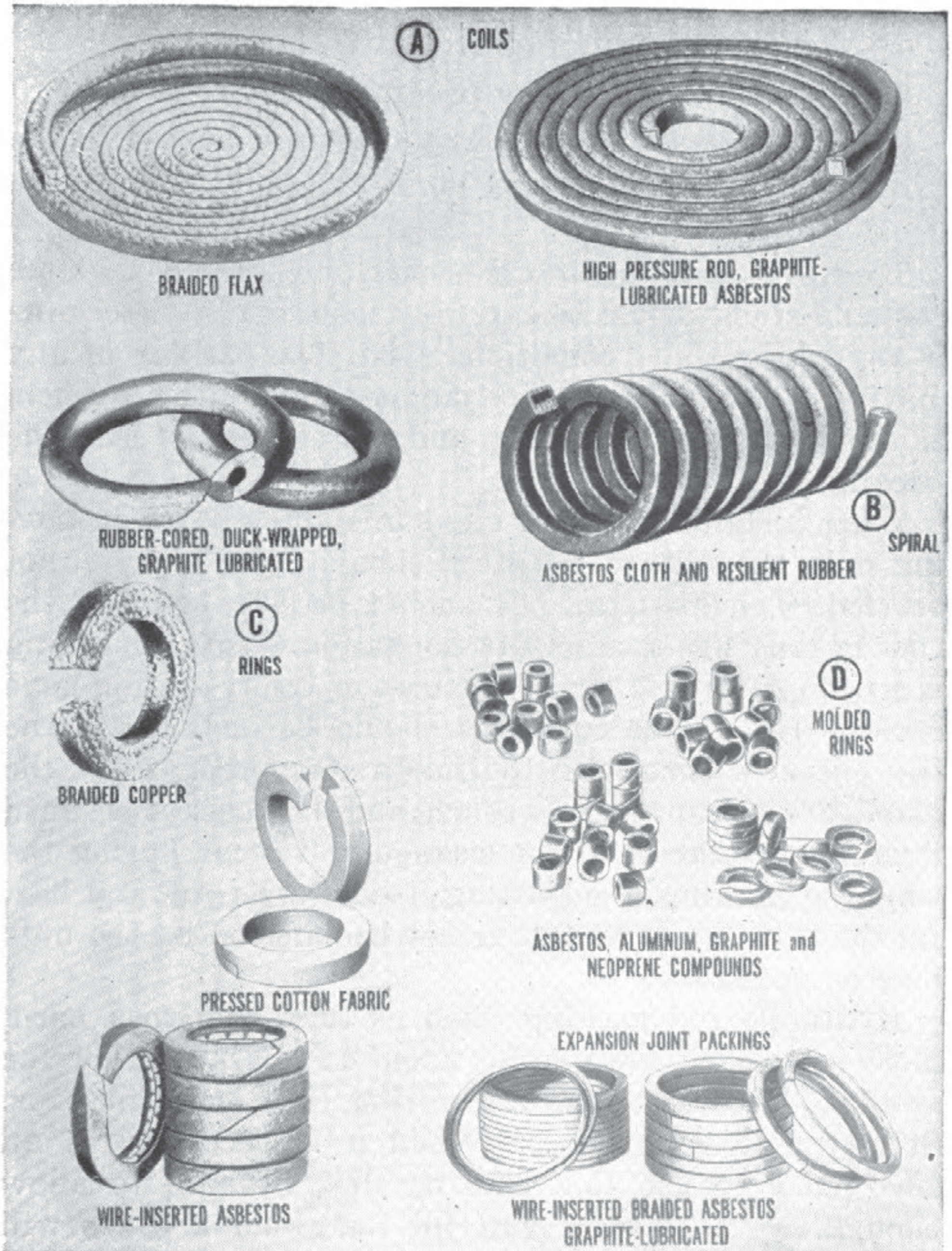
rotating shafts, and reciprocating pump rods. The packing material is compressed to the necessary extent and held in place by gland nuts or other devices.

The types of packing used for moving joints depends primarily on whether the seal is for a sliding or rotating joint. The most common forms used are coils, rings, spirals, and molded rings (fig. 9–31).

The packing of a SLIDING JOINT may be one of a large variety of types. High-pressure asbestos rod packing was formerly used exclusively for sealing steam joints (rods, valve stems, etc.). This type has been superseded to a large extent, however, by WIRE-INSERTED SQUARE-BRAIDED ASBESTOS, (for pressures up to 400 psi and temperatures up to 700° F) and by PLASTIC NON-METALLIC ASBESTOS ENCASED IN A BRAIDED WIRE COVERING (for pressures up to 650 psi and temperatures up to 850° F).

The SEALING OF ROTATING JOINTS is a more difficult problem than that of sliding joints. With this type of joint, it is possible for the packing to create enough friction to prevent the machine from operating. In the sliding joint, the heat of friction created by the packing is dissipated through the moving part of the joint. This does not happen in the rotating joint, where the friction heat builds up on the wearing faces of the packing and the shaft, unless other means are provided for its dissipation. Packings composed of materials with high heat conductivity properties, along with an allowance for leakage, take care of this heat dissipation in rotating joints. It is very important, however, that pressure applied to the packing be kept at the minimum which keeps the leakage within the allowable limits.

In the INSTALLATION OF ROD PACKING, care must be taken both to use the proper packing material and to detect and correct any deficiencies existing in the joint itself. The best grade of packing cannot seal a rod effectively if:



Courtesy of U. S. Naval Institute

Figure 9–31.—Typical packing for moving joints.

1. The rod is bent, scored, or rusty.
2. The gland is cocked.
3. The stuffing box and gland are scored or nicked.
4. The gland is out of alinement with the shaft.
5. All the old, hard, dry packing is not removed.
6. The threads on the gland studs are burred to the extent that the setting up of the gland nuts is prevented.

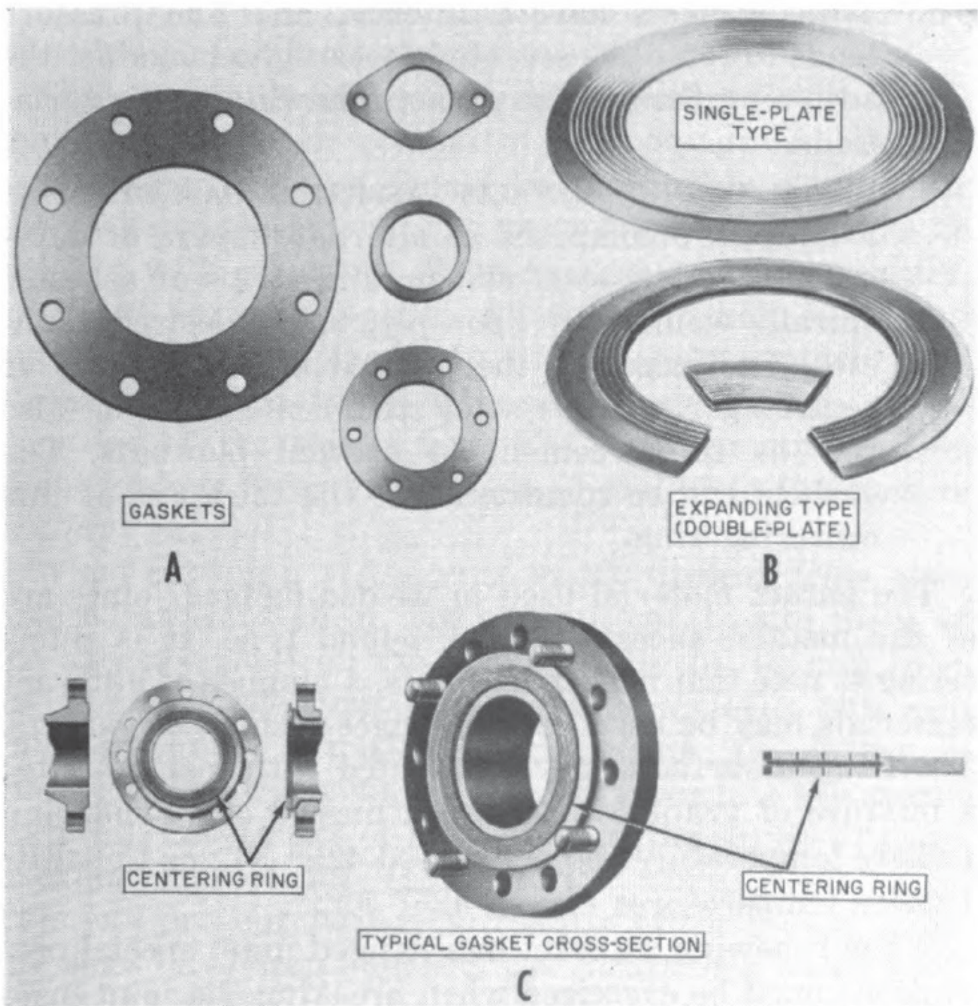
Whenever a stuffing box is broken down, the box, gland, rod, and studs should be carefully inspected to determine if any of the above conditions exist. The packing of any moving joint should never be jammed tight with a wrench, as this increases the friction and causes wear of both the packing and the rod.

When installing packing rings in stuffing boxes of moving rods, the ends of the rings should be cut square, not beveled. Enough clearance should be left between the ends of the rings to allow for elongation when the packing is set up. After any possible causes of faulty sealing have been corrected, the cut rings should be installed in the box one at a time with the joints staggered. Insert the gland, draw it up with a wrench, and then back it off until it is finger-tight. A slight leakage will occur during the time the packing is adjusting itself to the rod and box. As the packing expands, further backing off on the nuts may be necessary.

Hydraulic rod packing, such as tuck, and rock hard, must be soaked in water for about 12 hours to allow for swelling, before cutting and fitting in a pump plunger. Step-type joints are best. When it is necessary in an emergency to use this packing dry, be sure to allow enough clearance to provide for the swelling which will occur after the packing has absorbed moisture.

Packing of Fixed Joints

Fixed steam joints used to be satisfactorily sealed with gaskets of compressed asbestos sheet packing (fig. 9–



Courtesy of U. S. Naval Institute

Figure 9–32.—Fixed joint packing gaskets: (A) sheet asbestos gaskets; (B) serrated-face metal gaskets; (C) spiral-wound metallic-asbestos gaskets.

32A), but the 15 percent rubber content of the packing makes it unsatisfactory for modern high-temperature steam. Gaskets of corrugated copper or of asbestos and copper are sometimes used on low- and medium-pressure lines. The following two types of metallic or semi-metallic gaskets are in use in present-day high-temperature high-pressure installations:

1. SERRATED-FACE METAL GASKETS (fig. 9–32B), also made of Monel or soft iron, have raised serrations to make a better seal at the piping flange joints.

These gaskets have resiliency, and line pressure tends to force the serrated faces tighter against the adjoining flange. The gaskets shown are two variations.

2. SPIRAL-WOUND METALLIC-ASBESTOS GASKETS (fig. 9–32C), are composed of alternate layers of dovetailed stainless steel ribbon, and strips of asbestos spirally wound, ply upon ply, to the desired diameter. The gasket is then placed into a retainer or centering ring. The solid steel centering ring also acts as reinforcement to prevent blowouts. The gaskets can be compressed to the thickness of this centering ring.

The gasket material used in welded flanged joints are of the metallic-asbestos spiral wound type. It is interesting to note that in turbine joints, a number of different materials may be used on the flanges instead of gaskets. The flanged surfaces may be painted with manganesite; a mixture of graphite and boiled linseed oil; Usudurian (where temperatures do not exceed 425° F) ; or Copaltite (where temperatures exceed 425° F).

When renewing a gasket in a flanged joint, special precautions must be exercised when breaking the joint, particularly in steam and hot-water lines, or in salt-water lines which have a possibility of direct connection with the sea. Care should be taken that:

1. There is no pressure on the line.
2. The line pressure valves including the bypass valves, are firmly secured, wired closed, and tagged.
3. The line is completely drained.
4. At least two flange-securing bolts and nuts diametrically opposite remain in place until the others are removed, then slackened to allow breaking of the joint, and removed after the line is clear.
5. Precautions are taken to prevent explosions or fire when breaking joints of flammable liquid lines.

6. Proper ventilation is ensured before joints are broken in closed compartments.

These precautions may prevent serious explosions, personnel scaldings, or compartment floodings. All sealing and bearing surfaces should be thoroughly cleaned for the gasket replacement. The gasket seats should then be checked with a surface plate, and scraped as necessary, to afford uniform contact. All damaged bolt studs and nuts should be replaced. In flanged joints which have raised faces, the edges of gaskets may extend beyond the edge of the raised face. For complete information about gaskets refer to chapters 48 and 95 in the *Bureau of Ships Manual.*

When cutting a PLAIN FULL-FACED GASKET from compressed asbestos sheet, lay an appropriate size piece of the asbestos sheet on the flange. Scribe in the bolt holes and flange circle lines with light blows of a ball-peen hammer. Using a gasket punch, about $\frac{1}{16}''$ larger in diameter than the bolts, cut the bolt holes into the gasket material. Use a piece of hard wood as the supporting and backing surface for the material while punching it. This will prevent damage to the lips of the punch. After the holes have been punched, use shears or a sharp knife to cut the center and outside circles to form the ring.

Identification of Packing

The Navy symbol numbers which identify the numerous standard packings employed have four digits. The FIRST DIGIT indicates the class of service, the numeral 1 indicating a moving joint (rods, shafts, valve stems, etc.), and the numeral 2 indicating a fixed joint (flanges, bonnets, etc.). The SECOND DIGIT indicates the predominant material of which the packing is composed, as asbestos, vegetable fiber, rubber, metal, etc. The THIRD AND FOURTH DIGITS indicate the different styles of packing. You can determine the correct type packing for a specific use by referring to the packing and gasket charts posted in the machinery spaces.

Packing Precautions

The following general precautions should be observed with regard to the use of packings:

1. Do not use metallic or semimetallic packing on bronze or brass shafts, rods, plungers, or sleeves. Where this is done, scoring may result. Use a braided packing that is lubricated throughout, or a nonmetallic plastic packing in the center of the box, with an end ring of the braided packing at each end of the box.
2. Do not use a packing frictioned with rubber or synthetic rubber of any kind on rotary or centrifugal shafts. Such packing will overheat.
3. Do not use braid-over-braid packing on rotary or centrifugal shafts. The outer layer will wear through quickly, and eventually the packing will become rags.
4. Do not use packing with a rubber binder on rotary type compressors. It will swell and bind and, thereby, develop excessive frictional heat. The use of flexible metallic packing is recommended, or a lead-base plastic packing alternated with the flexible metallic packing can be used.
5. On hydraulic lifts, rams, and accumulators use a V-type packing. For water, this packing should be frictioned with crude, reclaimed, or synthetic rubber. For oils, the packing should be frictioned with oil-resistant synthetic rubber.
6. Do not use a plastic packing, such as symbol 1433 or 1439, alone on worn equipment or out-of-line rods; it will not hold. A combination of 1433 with end rings of plain braided asbestos (1103), or flexible metallic packing (1430), may be satisfactory for temporary service, until defective parts can be repaired or replaced.

7. Do not use a soft packing against thick or sticky liquids, or against liquids having solid particles. This packing is too soft to hold back such liquids as cold boiler fuel oil, and usually gets torn. Some of the solid particles which may be suspended in these liquids embed themselves in the soft packing, thereafter acting as an abrasive on the rod or shaft. Flexible metallic packing is best for these conditions.

QUIZ

1. How is pipe size designated when the inside diameter measures under 12 inches? When over 12 inches?
2. What are the three IPS designations for indicating the thicknesses of pipe walls?
3. Will a 1-inch standard pipe and a 1-inch extra strong pipe both have the same outside diameter? Will both have the same inside diameter?
4. How are sizes of copper tubing designated?
5. What piping material is used for pipe which transfers salt water?
6. What general care should be taken of uncovered and ungalvanized steel or iron piping?
7. What may result from an unremedied small leak in a gasket of a piping joint?
8. What may be done to remedy piping joint leaks resulting from improper allowance for expansion? From excessive vibration?
9. For what purpose is the threaded pipe union used most generally?
10. Are bolted flange pipe joints suitable for all pressures now in use aboard ship?
11. What are the three general classes of welded joints?
12. Below what temperature may silver brazed joints be used in steam piping? Below what pressure in cold lines?
13. What four types of expansion joints are installed in long steam lines?

14. How is the lower disk of a double-poppet type throttle valve removed for repairs?

15. What are sentinel valves? What is their purpose?

16. When is an excess-pressure pump governor employed in preference to the constant-pressure pump governor?

17. Why should the steam line to a siren be kept constantly drained of condensate?

18. What two things cause a small valve leak to become larger over a period of time, if it is not promptly corrected?

19. What two remedies are tried first to correct leaking valve stuffing boxes?

20. What types of valves permit the repacking of their stuffing boxes while they are under pressure?

21. If the disk of a valve with a yoke-type bonnet is bound to its seat, as a result of having been jammed shut while hot, what should be done?

22. What two things may cause the valve disk to come loose from its stem?

23. What two machines may be used to reface the seat and disk of a valve? Which is preferred? Why?

24. How should refaced valve seats and disks be tested? What is the process called?

25. What four principal types of joints are packed?

26. Should the ends of packing rings installed in stuffing boxes of moving rods be beveled or square?

27. What are the two types of gaskets used in modern, high-temperature, high-pressure, fixed joints?

28. What should be done to the gasket of a fixed joint requiring frequent breaking?

29. In packing identification symbols, what does the second digit indicate?

30. What type of packing should be used on hydraulic lifts, rams, and accumulators?

31. What kind of packing should never be used against thick or sticky liquids, or against liquids having solid particles?

32. With what must hair felt be combined to be used effectively as an insulation on cold-water lines ranging in temperature from 50° to 90° F?

33. When practical, how is hot piping with temperatures up to 1500° F generally insulated?

34. How is the total thickness of insulation on a valve or pipe fitting made equal to that on the adjacent piping?

35. What can be done with magnesia heat-insulation blocks and sections broken in the process of removal for making repairs?

CHAPTER 10

DISTILLING PLANTS

This chapter on naval distilling plants and their units deals with general descriptions of various types of plants and the Machinists' Mates operating instructions in relation to these plants. Having read and studied the chapter, Auxiliary Equipment, in the training course, *Fireman,* NavPers 10520-A, you already know the basic operations of a distilling plant.

Evaporation followed by condensation is the only effective way to produce distilled water from raw sea or river water. This distilled water may be used as boiler feed water to maintain high heat transfer efficiency and to prevent excessive scaling and corrosion in a boiler, and it may be used for drinking, cooking, washing, etc.

Basically, all evaporators are alike in that each consists of a heating section to produce evaporation; a condenser, or distiller, to condense the vapors from the evaporator; and a combination preheater and cooler, to preheat the feed (sea) water, and to cool the distillate from the condenser.

Evaporators are classified as coil, submerged tube, basket, and flash type, with the latter two the most modern. In the coil type, high-pressure steam is usually used, causing excessive scaling. In the submerged-tube type, the liquid surrounds the tubes containing the steam. In the basket type, the feed water surrounds the steam in a corrugated basket. The flash type requires a drop in

pressure of the liquid to a point below the saturation pressure at the temperature of the water.

DISTILLING PLANTS IN GENERAL

Naval distilling plants are of two general types—the steam generated plant and the vapor compression plant.

STEAM DISTILLING PLANTS are operated by steam received directly or indirectly from the ship's power plant or auxiliary boilers. These plants are subdivided into two general groups—low- and high-pressure plants—which differ mainly in the pressures in the heating elements, and in the evaporator shell. The basic units of both groups, however, are the same, consisting of an evaporator and a distilling condenser. The low-pressure plants are further divided into such types as Soloshell double-effect plants, two-cylinder double-effect plants, and triple-effect plants. They may also be classified in accordance with their capacity—10,000, 20,000 or 30,000 gallons per day (gpd). Only low-pressure plants are now installed on most ships on active duty; high-pressure plants, however, may be found on a number of inactivated ships, and on a few active auxiliaries.

VAPOR COMPRESSION PLANTS require electrical energy for operation. These plants were developed primarily for use on submarines where the absence of a steam supply necessitates some other source of heat for evaporation.

In recent years the use of vapor compression distilling plants has been extended to small Diesel-driven surface vessels. There are two sizes of plants in current use—1000 and 2000 gpd capacity.

In the vapor compression distilling plant (fig. 10–1) sea water is led into the shell of a heat exchanger, and brought to the boiling point at atmospheric pressure by several electric immersion heaters. Vapor generated from the boiling sea water is conducted through a series of separators to the suction side of a motor-driven compressor. The vapor is compressed to about 5 psig and the

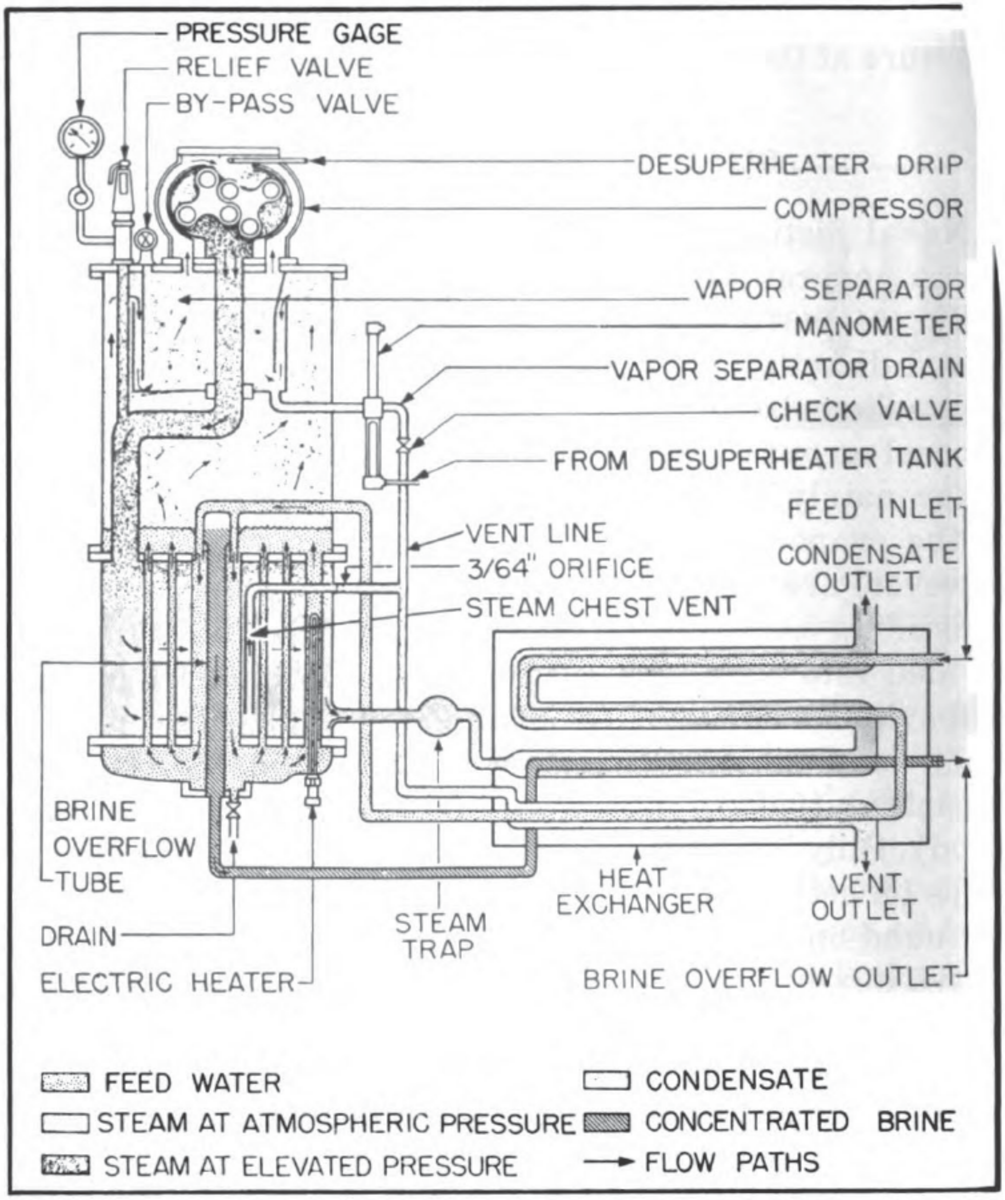
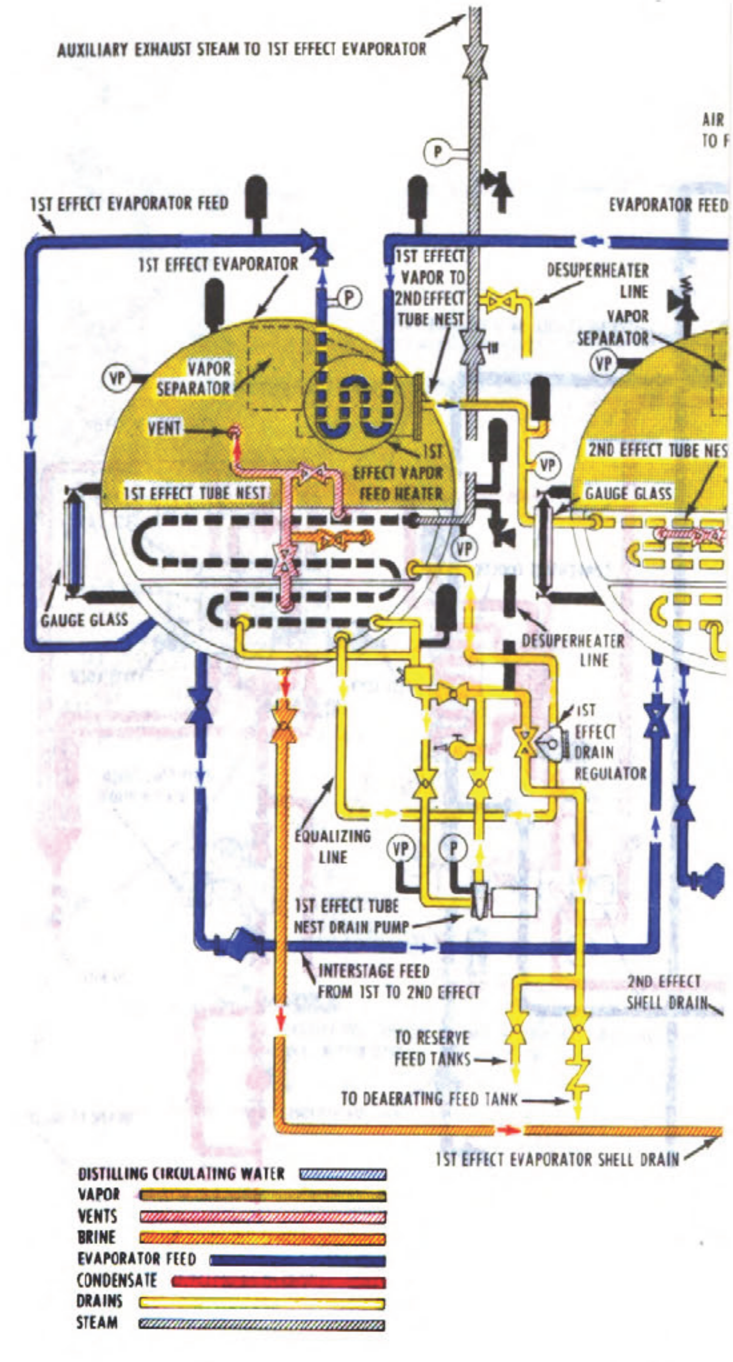


Figure 10-1.—Vapor compression distilling plant.

increase in pressure causes the temperature to rise to about 227° F. After compression, the vapor is led into the area surrounding the tubes of the evaporator unit and is used to furnish additional heat for boiling the sea water in the tubes. In the process of giving off its latent heat to boil the feed water in the tubes, the vapor condenses. The resulting condensate, which is relatively hot, is led through a feed heater to heat incoming feed water which is en route to the evaporating chamber.



AUXILIARY EXHAUST STEAM TO 1ST EFFECT EVAPORATOR
AIR
TO F
1ST EFFECT EVAPORATOR FEED
EVAPORATOR FEED
1ST EFFECT EVAPORATOR
1ST EFFECT VAPOR TO 2ND EFFECT TUBE NEST
DESUPERHEATER LINE
VAPOR SEPARATOR
VAPOR SEPARATOR
VENT
1ST EFFECT VAPOR FEED HEATER
1ST EFFECT TUBE NEST
2ND EFFECT TUBE NES
GAUGE GLASS
GAUGE GLASS
DESUPERHEATER LINE
1ST EFFECT DRAIN REGULATOR
EQUALIZING LINE
1ST EFFECT TUBE NEST DRAIN PUMP
INTERSTAGE FEED FROM 1ST TO 2ND EFFECT
2ND EFFECT SHELL DRAIN
TO RESERVE FEED TANKS
TO DEAERATING FEED TANK
1ST EFFECT EVAPORATOR SHELL DRAIN
DISTILLING CIRCULATING WATER
VAPOR
VENTS
BRINE
EVAPORATOR FEED
CONDENSATE
DRAINS
STEAM

Figure

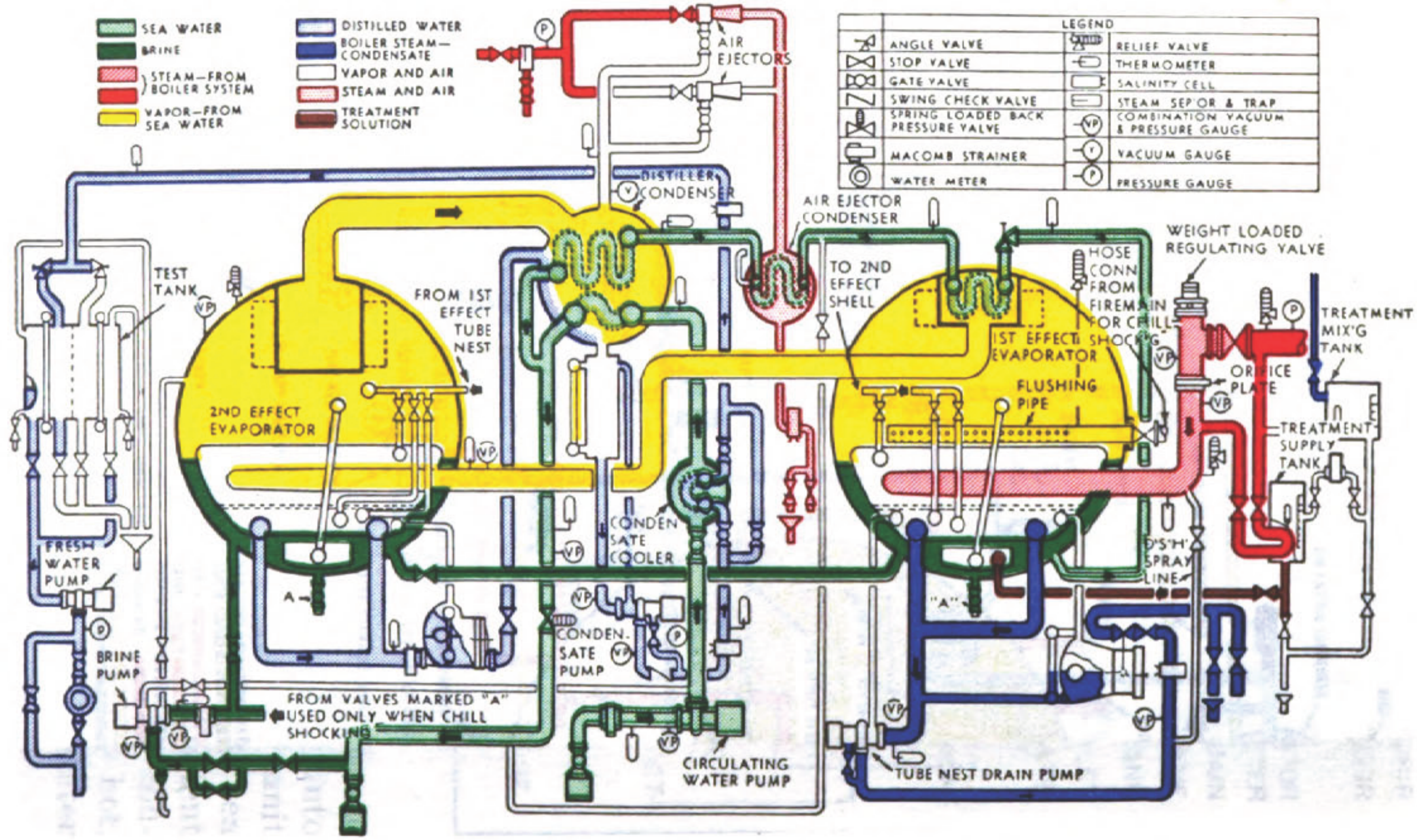


Figure 10–4.—Arrangement of a two-unit double-effect plant.

As you can see, after the electric immersion heater starts the boiling process in the evaporating chamber, there are two sources of heat for boiling the water in the evaporating chamber—the immersion heaters themselves and the hot compressed vapor which is led through submerged tubes within the evaporating chamber.

Low-Pressure Distilling Plants

Low-pressure steam distilling plants are ordinarily installed on all steam-driven vessels where an ample supply of auxiliary exhaust steam is available, and the daily capacity requirement for fresh water exceeds 4000 gallons. These plants are also installed on some Diesel-driven surface vessels where steam is supplied by an auxiliary boiler. Standard plants are built with nominal capacities of 4,000, 8,000, 10,000, 12,000, 20,000, 30,000 and 40,000, and 50,000 gpd. The ratings of the plants are based on an initial steam pressure of 5 psig to the tube nest of the first-effect evaporator. The four smaller capacity distilling plants are double-effect Soloshell or single-shell units. The diagrammatic arrangement of a Soloshell double-effect unit is shown in figure 10–2. The 20,000 gpd plants may be either two-shell double or three-shell triple-effect, while all 30,000, 40,000, and 50,000 gpd plants are three-shell triple-effect.

THE DIFFERENCE BETWEEN THE TRIPLE-EFFECT PLANT AND THE DOUBLE-EFFECT PLANT IS IN THE NUMBER OF STAGES OF EVAPORATION. IN THE DOUBLE-EFFECT PLANT, EVAPORATION TAKES PLACE IN TWO STAGES, WHILE IN THE TRIPLE-EFFECT PLANT EVAPORATION TAKES PLACE IN THREE STAGES. Figure 10–3 illustrates the diagrammatic arrangement of a triple-effect unit. The physical arrangement of the low-pressure, submerged-tube type distilling plants will vary considerably on different vessels. The principle of operation, however, will remain the same. All new destroyers and large combat vessels have two or more low-pressure plants installed aboard.

A brief discussion of the differences between the three

principal types of low-pressure distilling plants will give you a general idea of the plants you may work with. These three types are the Soloshell double-effect, the two-shell double-effect, and the three-shell triple-effect plants.

Two-Cylinder Double-Effect Plants

The most commonly used 20,000 gpd double-effect plant is built with two horizontal, cylindrical evaporator shells (fig. 10–4), one for each effect, and usually mounted with the axes of the shells parallel. Tube nests for both shells may be removed from the front head. The first-effect vapor feed heater is built into the upper part of the first-effect shell. In this design, the distilling condenser and the condensate cooler are built into separate shells, and usually mounted between the two evaporator shells. The air ejector condenser is also an independent unit and is mounted on one of the two shells.

Soloshell Double-Effect Plants

Virtually all low-pressure distilling plants up to and including the 12,000 gpd capacity plant are of the Soloshell double-effect type. This type consists of a single cylindrical shell mounted with the axis horizontal. A vertical partition plate (fig. 10–5), parallel to the axis, divides the shell into two evaporator chambers. Each of these chambers has a separate removable tube bundle bolted to the front head of the shell (the first- and second-effect coils in fig. 10–5). The first-effect vapor feed heater is built into the upper part of the first-effect shell, and also has a removable tube bundle bolted to the front head.

The distilling condenser (condensing and feed-heating sections) is built into the upper part of the second-effect shell. This unit does not have a removable tube bundle but the tube sheets project beyond the front and rear heads of the shell, providing access for cleaning or replacing tubes. The air ejector condenser is a separate unit, mounted on brackets on the evaporator shell. The condensate cooler is

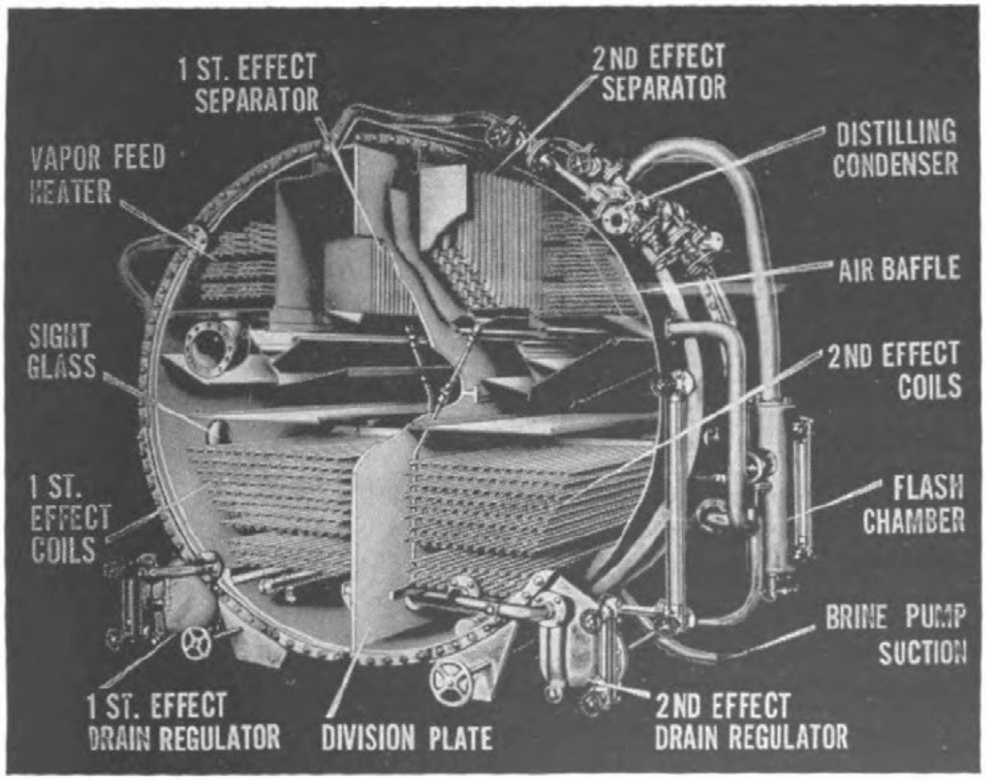


Figure 10–5.—Internal construction of a Soloshell distilling plant.

also in a separate shell and may be located wherever convenient for the necessary piping connections.

One type of 20,000 gpd capacity Soloshell double-effect plant is sometimes installed on light and heavy cruisers. Two such plants are installed when it is necessary to furnish an over-all capacity of 40,000 gpd. In such plants, the vertical partition separating the first and second effects is at right angles to the axis of the cylinder. The first-effect vapor feed heater is in the upper part of the first-effect shell; the distilling condenser is in the upper part of the second-effect shell, and the air ejector condenser is mounted on the main evaporator shell. The condensate cooler is mounted similarly to that in the smaller Soloshell plants.

The distilling plant's steam is obtained from the auxiliary exhaust line through a pressure regulating valve. This valve is set to maintain a constant steam pressure

of 1 to 5 psi to the tube nest of the first-effect evaporator. A pressure gage is installed ahead of the regulating valve. A relief valve, a thermometer, and a compound gage are installed on the steamhead of the evaporator tube nest in order to keep a check on the steam supply.

In passing through the reducing valve, the auxiliary exhaust steam is reduced to a pressure of 5 psi. The steam then passes through an orifice plate in the steam line between the reducing valve and the inlet to the first-effect tube nest. This orifice plate is designed to control the amount of steam entering the plant to an amount required for the plant's designed output of distilled water. A change in the size of the orifice would alter the plant output.

Because of the throttling effect in passing through the orifice plate, the low-pressure steam becomes superheated. The auxiliary exhaust steam is therefore passed through a desuperheating area in the steam line. Desuperheating is accomplished by a spray of hot water piped from the first-effect tube nest drain pump. This water is sprayed into the steam supply line in sufficient quantity to reduce the steam temperature to that corresponding to the pressure existing in the tube nest.

After being desuperheated, the steam passes into the first-effect tube nest. Here the steam gives up its latent heat of vaporization to the feed water surrounding the first-effect tubes. The resulting condensate (condensed steam) from the first-effect tube nest is discharged to the deaerating feed tank. In an emergency, the condensate may be discharged to the main condensers, the auxiliary turbogenerator condensers, or the fresh water drain collecting system. This condensate is returned to the boiler feed system to help maintain the heat and water level of that system constant.

When a ship is in port or at anchor, the supply of auxiliary exhaust steam may not be sufficient to operate the distilling plant. To overcome this deficiency, 150 psi steam is introduced to the system through a pressure-reducing

valve. Additional steam may also be supplied by "bleeding" the ship's service generator turbines.

Steam generated in the evaporator shells by the evaporation of the feed water is referred to as VAPOR, to prevent confusing it with the steam which is introduced into the first-effect evaporator tubes and is the outside source of heat for the plant. The vapor is separated from the feed water at the water surface and, although the vapor itself is pure, small particles of raw, unevaporated feed water are mixed with it. The particles of feed water are removed from the vapor by a series of baffles above the surface of the water in the evaporator shell, and by additional baffles or vanes in the first-effect VAPOR SEPARATOR.

The vapor changes its direction of motion several times in passing around the hooked edges of the baffles and vanes. The hooked edges trap particles of feed water and drain them into pipe lines. These pipe lines discharge the separated moisture as far away as possible from the tube nest in the evaporator shell.

After passing through the vapor separator on its way to the second-effect tube nest, the vapor passes through a VAPOR FEED HEATER. Part of the vapor is condensed as it gives up its latent heat to the water passing through the tubes of the heater. The remaining vapor and condensate pass together into the tube nest of the second-effect evaporator. Here the first-effect vapor gives up its latent heat in generating vapor from the feed water in the second-effect evaporator shell.

In the second-effect shell, the pressure surrounding the sea water (brine) is considerably less than in the first-effect shell. This makes it possible to use the vapor formed in the first-effect shell to boil and vaporize the sea water in the second-effect shell.

The vapor generated in the second-effect shell passes through a vapor separator and into a distilling condenser. The condensing tubes nearest the incoming vapor are utilized as a feed heating section where the vapor is par-

tially condensed, thereby heating the feed water circulating through the condenser tubes. The remainder of the vapor is condensed in the condensing section and is discharged to the test tanks as fresh water.

The condensate formed in the second-effect tubes is discharged through the second-effect tube nest drain regulator and led to the distilling condenser through the flash chamber.

The distilling condenser circulating water pump takes suction from the sea and discharges the water through the condensate cooler and the distilling condenser. A strainer is installed in the pump suction piping. If the pump is located above the light load waterline of the ship, an ejector primer is connected to a line leading from the fire main, and a check valve is installed in the pump suction piping to facilitate starting the pump. The cooling water passes through the shell of the condensate cooler and then through the tubes of the distilling condenser. The cooling water is then discharged overboard through a spring-loaded back-pressure valve set to maintain a back pressure of about 5 psig.

A portion of the sea water discharged from the cooling water circuit is used as feed to the first-effect evaporator. A 5 psi back pressure provides sufficient head to force water through the feed heater to the first-effect shell. The evaporator feed water is discharged into the second-effect vapor feed heater (shown as a U-bend in figure 10–2) which is located near the distiller condenser section of the shell. After passing through the second-effect vapor feed heater tubes, the feed water travels through the tubes of the air ejector condenser. From there, the feed water is led into the first-effect vapor feed heater tubes. After passing through the first-effect vapor feed heater, the feed water enters the first-effect shell through perforated internal feed distributing pipes located well below the working water level in the shell.

A portion of the feed water is evaporated after entering the first-effect shell. This increases the density, or salinity,

of the remaining portion. This denser or saltier water, commonly referred to as BRINE to distinguish it from sea water, is led into the second-effect shell.

The brine is transferred to the second-effect shell through a pipeline having a manually controlled feed regulating valve installed in it. The higher pressure in the first-effect shell is utilized to force the brine into the second effect, where it is distributed by means of perforated internal feed pipes. (In a triple-effect plant, the brine then passes to the third-effect shell through a pipeline and is distributed in a manner similar to that in the second-effect shell of a double-effect plant.)

A brine overboard pump takes suction from the second-effect shell through a Macomb-type strainer, and discharges the brine into the distiller circulating pump overboard discharge line. To permit rapid draining of the first- and second-effect shells as when chill shocking, they have suction connections leading directly to the brine overboard pump. Since these connections are not used in normal operations, they are provided with valves that can be locked closed to prevent accidental opening, which would upset proper operations of the plant.

Triple-Effect Plants

The triple-effect distilling plant is similar to the double-effect plant except that the triple effect has an intermediate evaporating stage. A standard 20,000 gpd triple-effect plant consists of three horizontal, cylindrical shells (fig. 10–6) set side by side with their axes parallel. The tube bundles can be withdrawn from the front cover of each shell. The first- and second-effect vapor feed heaters are built into the front end of the second- and third-effect evaporator shells. The distilling condenser is contained within the third-effect shell. The air ejector condenser and the condensate cooler are in separate shells and are mounted on the third-effect shell. Figure 10–6 illustrates the internal arrangement of a first-effect evaporator shell of a triple-effect plant.

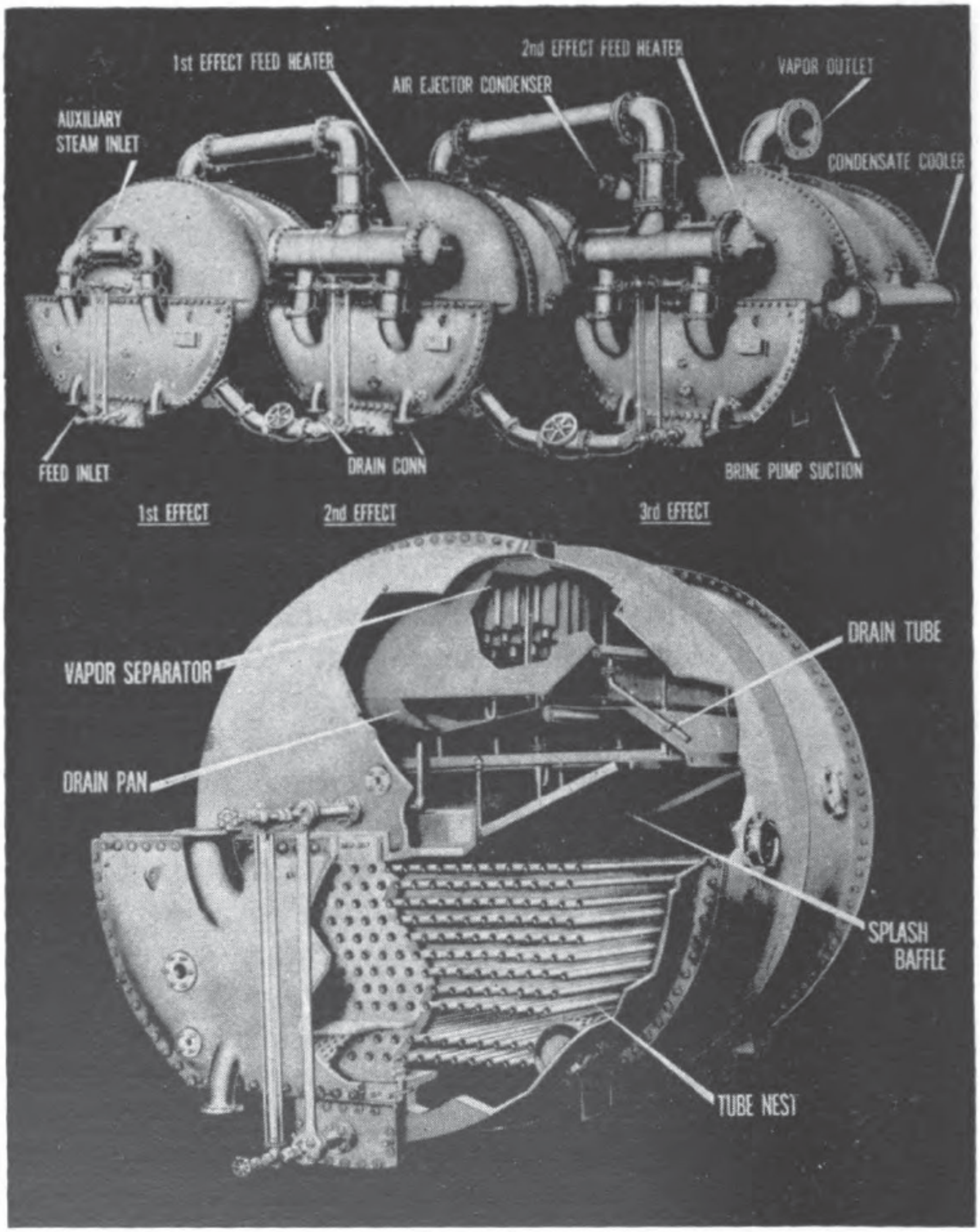


Figure 10–6.—Internal arrangement of a first-effect evaporator shell of a triple-effect plant.

Another 20,000 gpd triple-effect design consists essentially of three horizontal shells bolted together end to end, with vertical partition plates between each section (shell) to form the three effects. The tube bundles can be withdrawn horizontally through one side of the cylinder. Vapor separators in independent shells are installed in

the vapor piping between effects (cylinders), and between the third effect and the distiller condenser. The first- and second-effect vapor feed heaters are in separate shells and are mounted in the piping at the inlet to the second- and third-effect tube bundles, respectively. The two sections of the distilling condenser and the condensate cooler are built into a single shell and independently mounted as space and piping arrangements may permit. The air ejector condenser is also a separately mounted unit.

The standard 30,000 gpd triple-effect plant is similar to the standard 20,000 gpd plant, except for the increased size of the units.

There are two types of 40,000 gpd triple-effect plants which may be considered as standard, due to their wide use in naval vessels. The first type uses exactly the same arrangement as the standard 20,000 gpd triple-effect plant, with the size of the units and parts increased as necessary for the greater capacity. The second type consists of three horizontal shells, usually mounted side by side with axes parallel. The tube bundles can be withdrawn through the front end of the shells as in the 20,000 gpd two-shell double-effect plant. In this design, both vapor feed heaters and the distilling condenser are built as three independent units, each mounted separately outside the evaporator shells. The air ejector condenser and the condensate cooler are also in independent shells and are separately mounted outside the evaporator shells.

When you compare a low-pressure triple-effect distilling plant with a low-pressure double-effect plant, you will find that:

1. UNITS ADDED to the triple-effect plant include one evaporator shell, one vapor separator, one feed water heater, one feed pump, and several salinity cells. The evaporator feed pump takes suction from the cooling water circuit at a point between the outlet of the condensing section of the distiller condenser and the spring-loaded back-pressure valve.
2. The SALT WATER FEED is piped successively from the

first-effect shell to the second- and third-effect shells. The water decreases in heat and increases in density as it progresses from the first to the third effects.

3. The BRINE DISCHARGE is made from the third-effect shell instead of from the second-effect shell.
4. The GENERATING HEAT in the tube nests of the second- and third-effect shells is derived from the vapor created in the preceding shell.
5. The VACUUM is increasingly higher in each successive evaporator shell and in the plant as a whole, as the distance from the air ejector and the distilling condenser is decreased. This higher vacuum, lowering the boiling point, makes it possible to generate vapor with the lower over-all temperatures of the sea water or brine and the vapor filled tubes.

UNIT PARTS OF TRIPLE-EFFECT DISTILLING PLANTS

The principal parts of a modern low-pressure triple-effect distilling plant include the tube nests, distilling condenser, vapor feed heaters, level controllers, air ejector, flash chamber, air ejector condenser, condensate cooler, and tube-nest drain regulator.

Evaporator Tubes

The evaporator tubes are made of either copper-nickel alloy or copper-zinc-tin alloy (admiralty metal). The tube bundle (fig. 10–5) consists of two sets of tubes—an upper set of either eight or nine rows of horizontal tubing, and a lower set of two or three rows of similar tubing. Tube ends are inserted into and expanded to fit tightly in holes in the front and rear tube sheets (fig. 10–6). Both front and rear tube sheets are provided with flanged heads or cover plates. The internal areas of the tubes and heads thus form the steam coil. The front head and tube sheet are flanged to the front head of the shell cylinder. The rear tube sheet and head, and an intermediate tube supporting plate are supported inside the shell cylinder by rollers which are mounted on rails. This "floating head"

design permits unrestricted expansion and contraction of the tube bundles. In addition, this type of construction permits removal of the tube bundles for cleaning.

Distilling Condenser

This condenser consists mainly of a bank of tubes through which the cooling sea water flows, a baffle plate

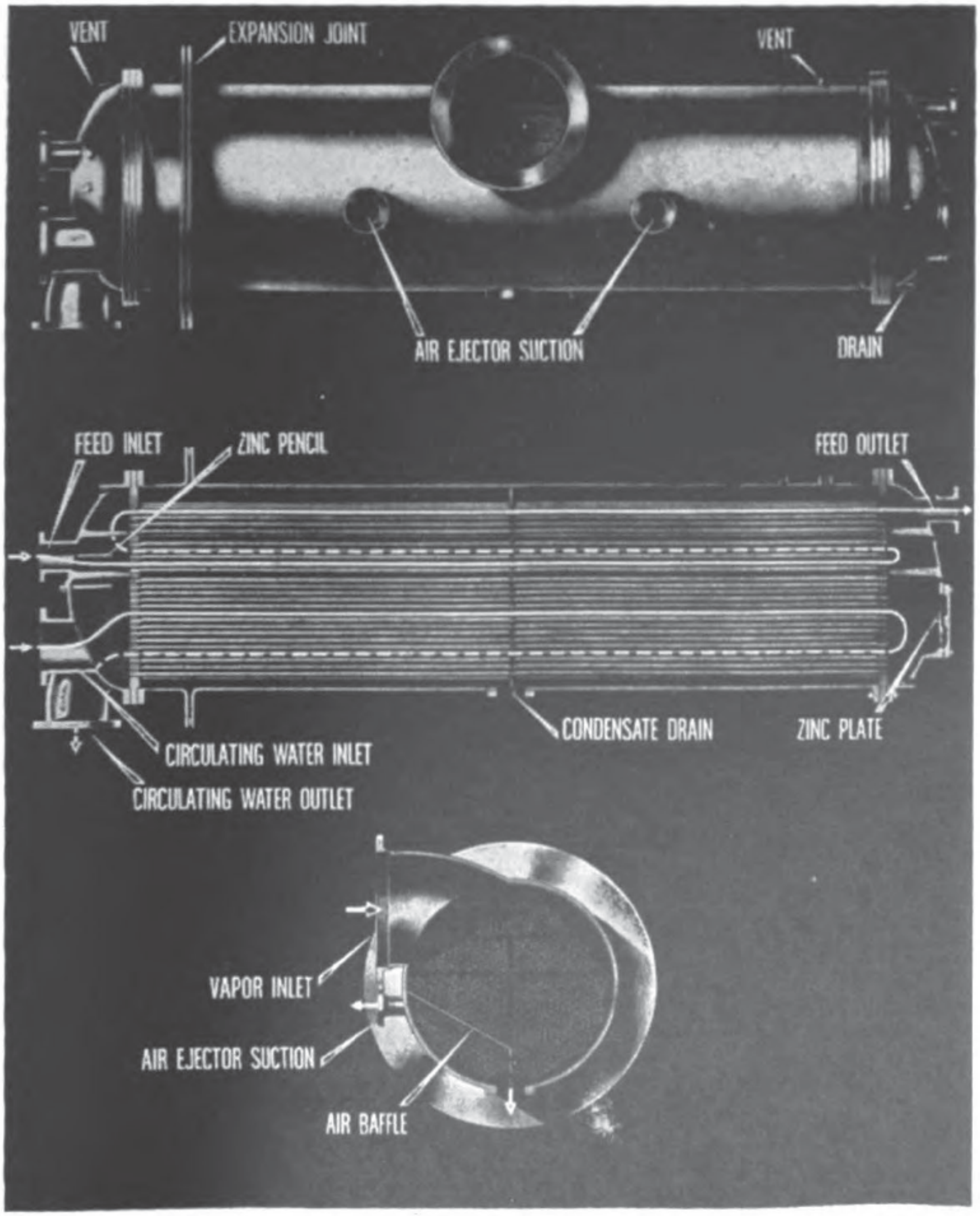


Figure 10–7.—Distilling condenser.

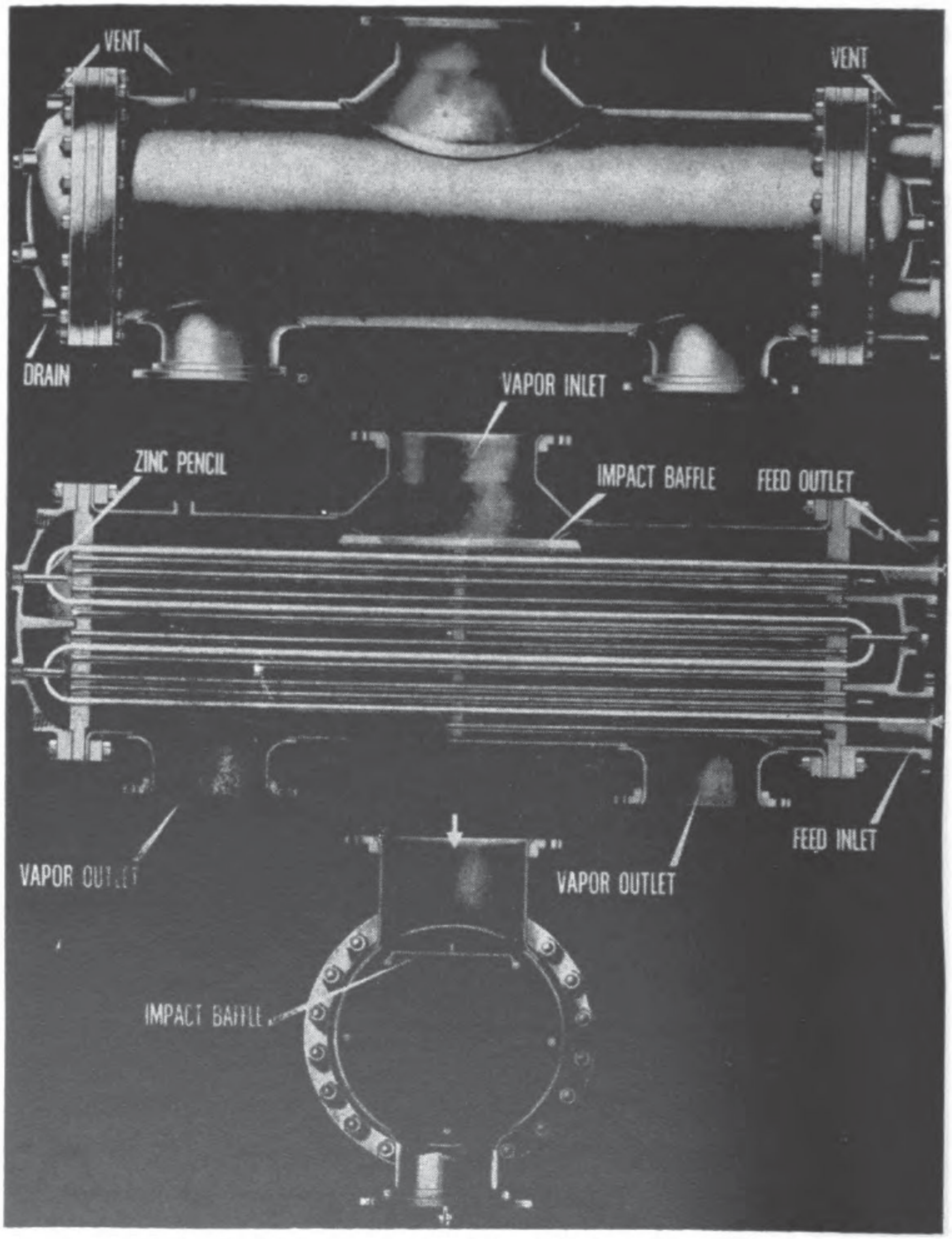


Figure 10–8.—Vapor feed heater.

which deflects the water vapor away from the air precooling section, a section of tubes known as the inner heating section, and an outside shell.

On the feed inlet end of the condenser there is a zinc pencil, and at the outlet end a zinc plate is installed. In standard designs, the condensing unit is generally built into the third-effect shell. The distilling condenser of the Soloshell double-effect plant is built into the upper part of the second-effect shell (fig. 10–4). However, in some distilling plants the condenser is a separate unit, such as that illustrated in figure 10–7.

Vapor Feed Heaters

The number of vapor feed heaters in a distilling plant varies from one to three, depending upon the number of effects and the design of the plant. The feed water passes through the tubes in these heaters on its way to the first-effect shell. Vapor from one of the evaporator shells passes into each heater and flows around the heater tubes, thus heating the feed water. A typical vapor feed heater is shown in figure 10–8.

Level Controllers

In practically all of the distilling plants built prior to 1950, the water level in the shell of each effect is controlled by manually regulating the individual feed inlet valves. Many of the plants built since that date, however, are provided with automatic feed-level control devices. These adjustable weir type level controllers (fig. 10–9) are located in the brine discharge from each effect. The feed from each effect to the next is only the amount of brine that spills over the weir and is the excess of feed over evaporation in that effect.

The weir proper is carried on an adjusting screw which permits the height to be adjusted to any desired operating level. The bottom of the weir chamber is water-sealed to prevent equalizing shell pressures.

The level controllers consist of a chamber in parallel

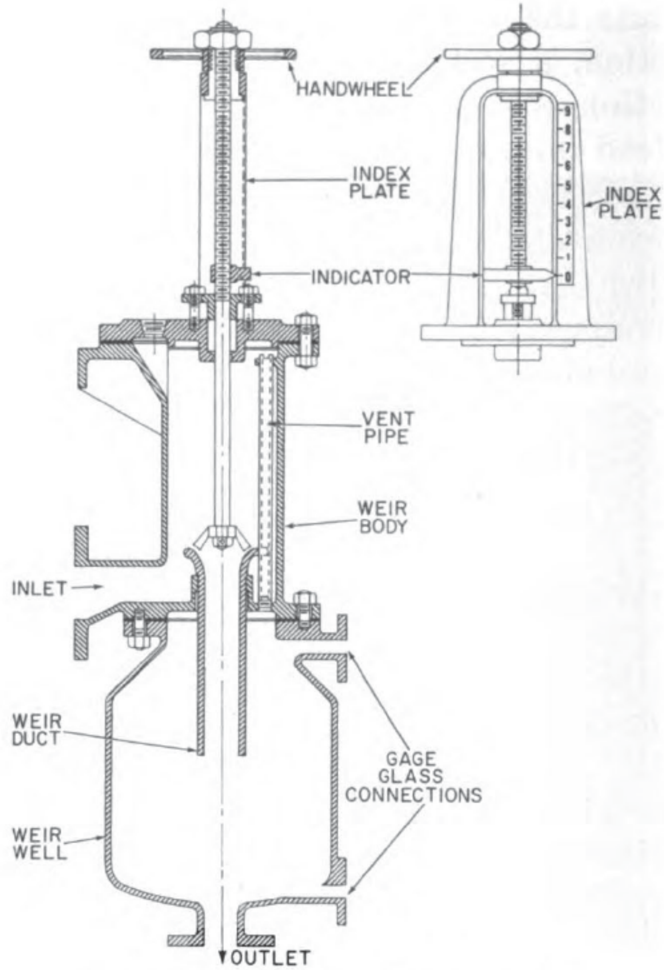


Figure 10–9.—Weir type level controller.

with the evaporator shell. A weir pipe within each evaporator shell discharges into a weir well. Feed water in excess of that which is evaporated spills over the weir pipe and into the weir well.

The internal weir pipe may be raised or lowered by the external handwheel. The weir well vents into the weir chamber by a pipe which also serves as a guide for the weir pipe. A gage glass is installed on the weir well.

Flowrator

Some distilling plants may be equipped with a flowrator or some other visual flow indicator in the evaporator feed line. Flowrators are calibrated in gallons per minute

(gpm) and it is possible to set the rate-of-feed by adjusting a hand valve in the feed line. In order to maintain the proper density (1.5/32) in the last-effect shell, three gallons of sea water feed must be fed into the distilling plant for each gallon of distilled water produced. The remaining two gallons of sea water are pumped overboard. The flowrator compares the amount of incoming feed against the amount of brine leaving the last effect, thus making it simple to keep the feed rate adjusted correctly.

Solenoid Valve

If weirs are installed on evaporators, a three-way solenoid trip valve is usually provided to divert the output to the bilge whenever the purity is unsatisfactory. The solenoid valve is tripped automatically whenever the salt content at the condensate cooler outlet exceeds 0.25 grains per gallon (gpg) or 0.065 equivalent parts per million (epm). When this occurs, the distillate continues to flow to the bilge and an alarm is sounded on the conductivity meter panel.

The solenoid valve is so wired that flow can be directed to the ship's tanks only when the solenoid is energized. An increase in salinity to more than 0.25 gpg (0.065 epm) deenergizes the solenoid and trips the valve to the bilge. This arrangement makes it impossible to reset the valve to discharge to the ship's tanks until the salinity is below 0.25 gpg (0.065 epm) and the solenoid is again energized. In the event of a power failure at the panel, the solenoid valve will trip and discharge to the bilge.

Air Ejector

The function of air ejectors is to remove the noncondensable gases, mainly air, which may leak or be discharged into condensers operating under a vacuum. The air ejector (fig. 10–10) is a comparatively simple mechanism consisting of a steam inlet and nozzle, an inlet for the saturated air from the condenser, and a diffuser tube.

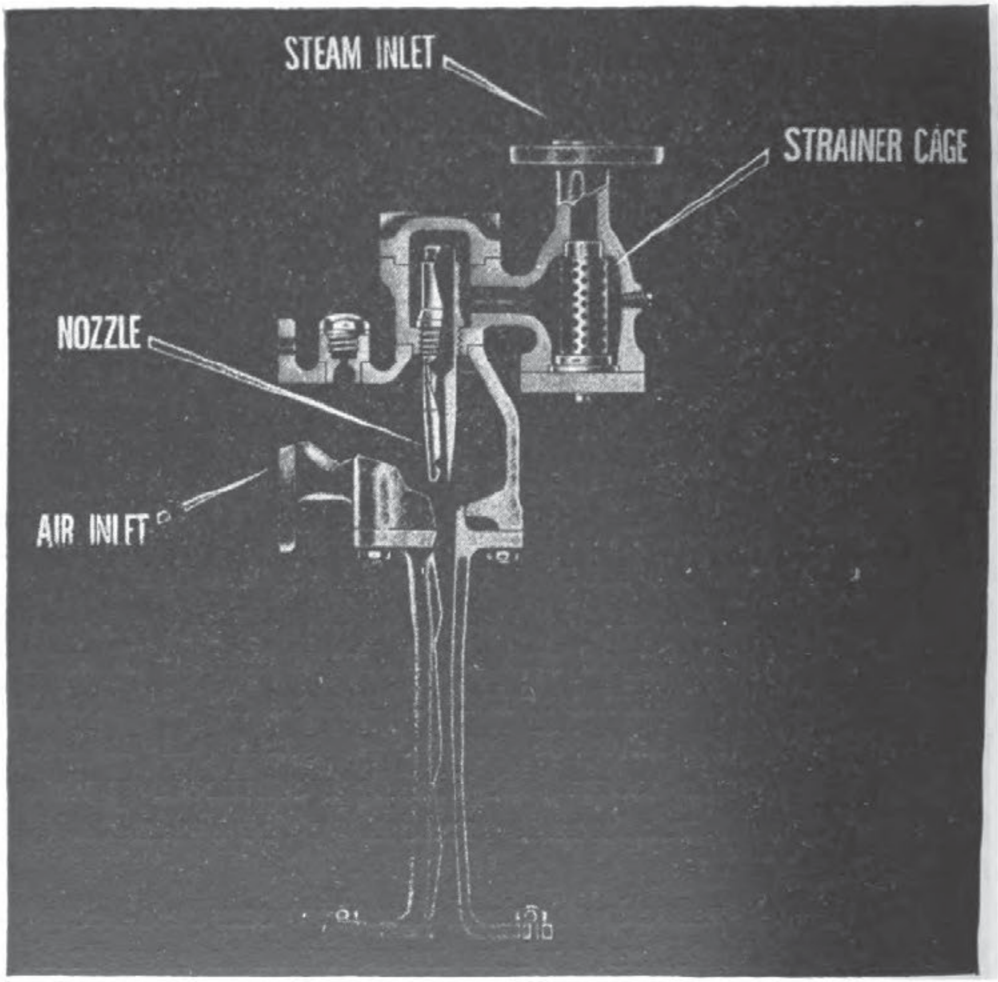


Figure 10–10.—An air ejector.

Steam (125 to 135 pounds) is led to the air ejector and passes through the nozzle. The steam attains a high velocity as it passes from the nozzle. The high-velocity steam jet issuing from the nozzle creates a suction and draws in the saturated air from the distilling condenser. Two air ejectors are usually provided for each distilling plant; however, one unit is sufficient to operate the plant.

Air Ejector Condenser

The steam-air mixture which is discharged from the air ejector is normally condensed in a shell-and-tube type of air ejector condenser (fig. 10–11). This is nothing more than a bank of tubes divided by a series of baffles

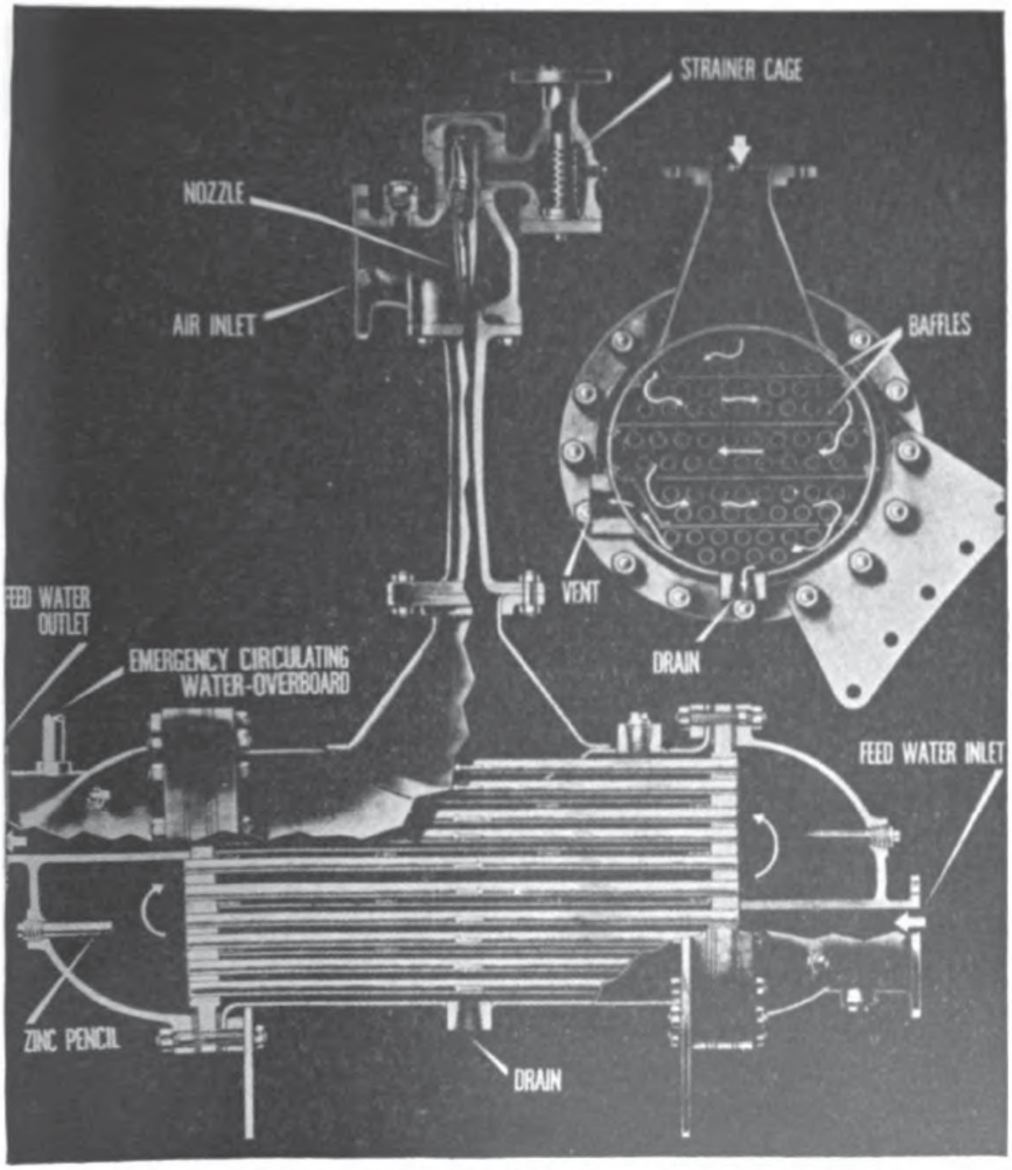


Figure 10–11.—An air ejector condenser.

and enclosed in a shell. The baffles ensure that the steam-air mixture and condensate (water) pass over the entire cooling surface of the tubes before reaching their outlets. The resulting condensate is led into the low pressure or open funnel drain system and from there to the boiler-feed system.

Condensate Cooler

The condensate cooler (fig. 10–12) is a tubular surface multipass heat exchanger. The fresh water (condensate)

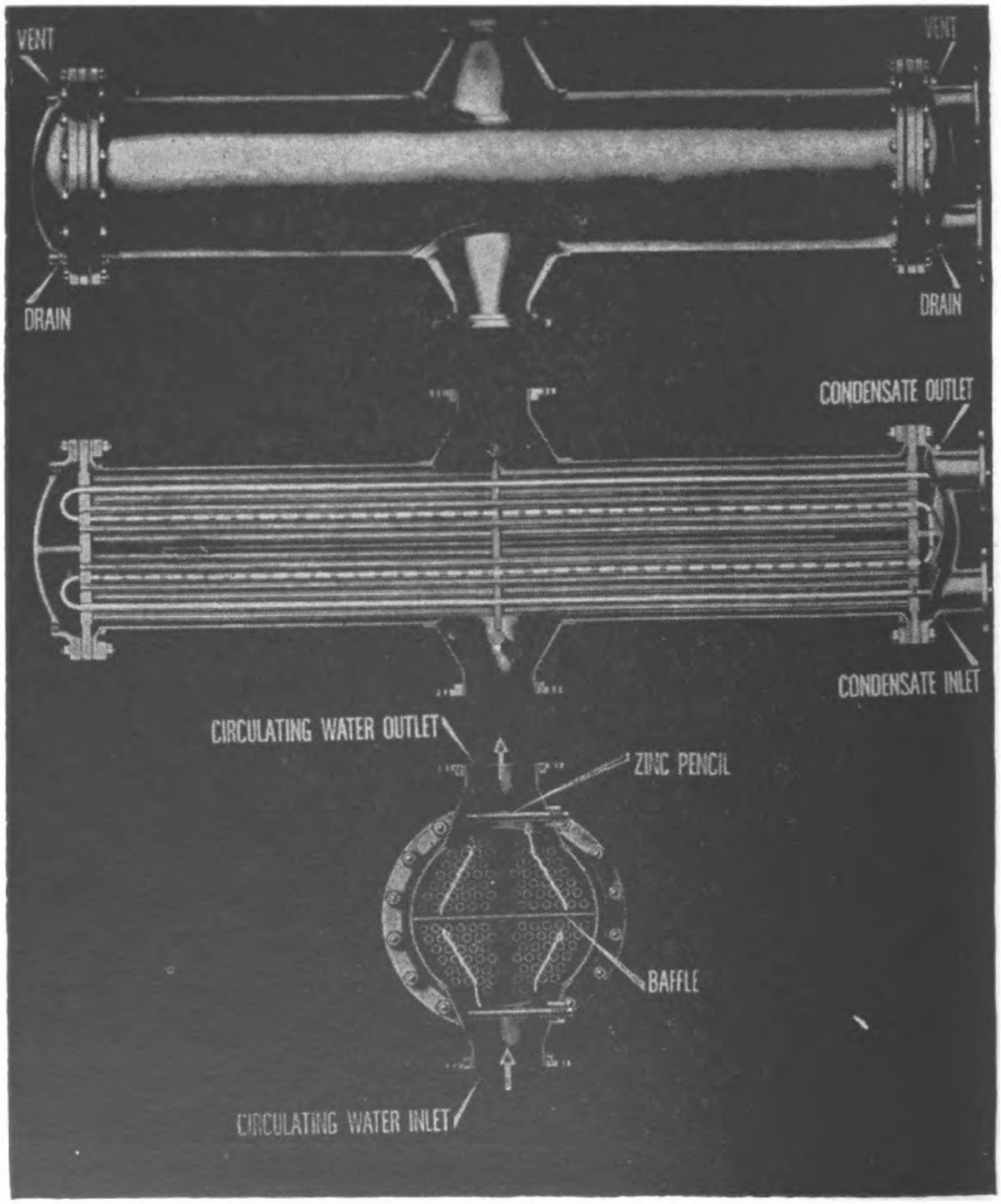


Figure 10–12.—Condensate cooler.

from the distiller condenser is drawn out by the condensate pump and discharged through the tubes of the condensate cooler. From here the condensate is further drawn out by the fresh water pump and discharged to the test tanks.

Sea water flows in a single pass through the shell and around the tubes, thus cooling the condensate.

Flash Chamber

The flash chamber is essentially a receptacle within which the second-effect drains are reduced to a pressure and temperature corresponding to the distilling condenser vacuum. The flash chamber is attached or located on the third-effect side of the evaporator shell.

Tube-Nest Drain Regulator

A tube-nest drain regulator (fig. 10–13) is installed in the drain line from each evaporator coil. The drain

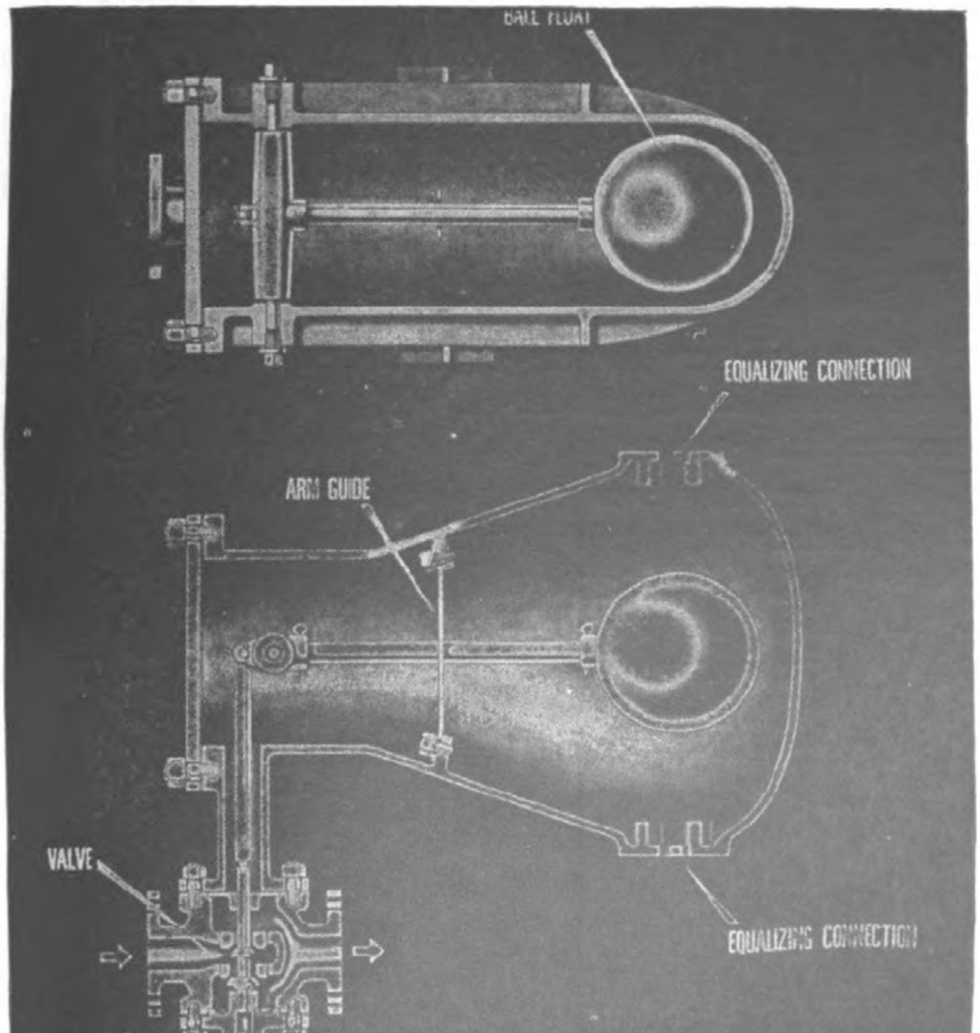


Figure 10–13.—Tube-nest drain regulator.

regulator consists of a body and cover enclosing a balanced cage or rotary valve operated by a ball float. The drain regulator prevents the generating steam from blowing through the tube bundle in the first and second effect.

Pumps

Distilling plant pumps should always be operated at the speed stamped on the pump nameplate, regardless of the fact that variable speed motors may have been provided.

OPERATING LOW PRESSURE DISTILLING PLANTS

Low pressure distilling plants are designed to produce their overload capacity with 5 psig steam pressure in the first-effect tubes, and a 26-inch vacuum in the last-effect shell, even though the tubes are moderately coated with scale.

Starting a Manually Operated Double-Effect Plant

TO START A LOW-PRESSURE DISTILLING PLANT when the evaporators are empty and all pumps have been secured, proceed as follows:

1. Open all valves and air vent cocks in the distiller circulating water line and start the distiller circulating water pump.
2. Adjust the spring loaded back pressure valve in the circulating water overboard line to maintain a pressure of 5 psig on the feed pump suction.
3. Open all valves and air cocks in the evaporator feed system and the brine overboard line, except the brine pump discharge valve and the air ejector condenser emergency circulating water overboard valve.
4. Start the evaporator feed pump.
5. When a water level of 10 to 13 inches appears in the second-effect shell, start the brine overboard pump, and crack open the discharge valve on this

pump. The brine overboard valve at the ship's side and the valve in the suction to this pump should always be wide open during operation.

6. Open the air ejector emergency circulating water valve for cooling purposes. Check the air vent on the after condenser to be sure the vent is not clogged. Do the same for the drain from the after condenser. Now open the gate valve at the suction of the air ejector unit which is to be cut in; and admit steam to the air ejector nozzle. All vents from the steam head to the evaporator shells should be wide open. Test the condensate from the air ejector condenser before directing it back to the boiler feed system.
7. When the second-effect evaporator shell indicates about 16" of vacuum, partially open the first-effect steam valve. When condensate appears in the first-effect drain regulator, drain off some of the condensate and test it. If the condensate is salty, discharge it to the bilge until the chlorinity drops to acceptable boiler feed value. If the condensate is acceptable, start the first-effect tube-nest drain pump after having adjusted the valves from the pump so that the condensate will be directed to the deaerating feed tank in the engineroom.
8. When a condensate level appears in the second-effect automatic drainer gage glass, open the discharge valve at the drainer and when condensate appears in the flash chamber gage glass, open the valve at the condensate pump suction.
9. Start the condensate pump and open all valves in the discharge line from this pump to the test tank. When water appears in the gage glass of the test tank, draw off some of the distillate and test it. If the distillate is not of sufficient purity, discharge to the bilges.
10. Open all the required valves in the fresh water system, except the fresh water pump discharge.

Start the fresh water pump and regulate the discharge valve to maintain a desired level in the test tank. Close the bypass valves around the water meter so production can be recorded.

11. As the output of the plant is gradually increased, the feed valves should be adjusted to the desired position. When sufficient feed water is flowing through the air ejector condenser, close off the emergency circulating water valve. The valves in all vent lines should be adjusted to their normal operating position. When the first-effect steam pressure and the second-effect vacuum both have attained their desired values, the density of the brine pump discharge should be checked. Carefully manipulate the brine overboard control valve until the brine density reaches the desired value.
12. If the flow of evaporator feed through the air ejector condenser is stopped temporarily, such as when correcting high feed level in the first-effect evaporator shell, vapor may discharge into the evaporator room through the air ejector condenser vent pipe. This condition may be remedied by slightly opening the valve in the overboard line from the feed outlet of the condenser to permit the circulation of water through the after condenser and overboard. This valve should not be opened more than is required in order to prevent an excessive amount of heated feed water being discharged overboard. When, for any reason, the meter gage indicates that the distillate contains excessive chlorine, immediately adjust the valves in the condensate discharge line so that the impure water is discharged to the bilge instead of the fresh water tank.

Securing a Manually Operated Double-Effect Plant

THE CORRECT PROCEDURE FOR SECURING A MANUALLY-OPERATED LOW-PRESSURE DISTILLING PLANT begins by

notifying the engineer officer of the watch that the evaporator plant is ready to be secured. When permission to secure has been granted, proceed as follows:

1. Secure exhaust steam to the first-effect tube nest and the discharge from the first-effect tube nest drain pump.
2. Secure the tube nest drain pump.
3. Secure the condensate pump.
4. Secure the fresh water pump.
5. Secure the suction and discharge to the fresh water meter.
6. Secure the steam to the air ejector.
7. Open wide all air vents to equalize pressures in all units.
8. Allow the circulating pump, evaporator feed pump, and brine overboard pump to continue operating for a few minutes to cool all parts of the distilling plant.
9. Secure the brine overboard pump.
10. Secure all pumps, suction and discharge, making sure that evaporator tube bundles are fully covered with water.
11. Close the sea injection valve and the brine overboard valve at the ship's side.
12. Secure the inlet and outlet valves of the second-effect tube nest drain regulator.
13. Secure the feed valves for each evaporator.

Starting an Automatic Plant

TO START AN AUTOMATIC LOW-PRESSURE DISTILLING PLANT when the evaporators are empty and all pumps have been secured, proceed as follows:

1. Open wide all valves in the circulating water circuit from the sea suction to the overboard discharge.
2. Start the circulating pump. Pumps must not be

run dry. Before starting any pump, make certain that the suction, vent, and gland seal valves (where provided) are open, and that the pump casing is full of water. On centrifugal pumps, it is preferable to leave the discharge valve closed until after the pump has been started.

3. Check to see that the spring-loaded back-pressure valve is properly adjusted to maintain 5 psi in the discharge line from the distilling condenser.
4. Open all air vent cocks on the distilling condenser, vapor feed heater, and air ejector condenser heads until the air is expelled, then close the vent cocks.
5. If evaporator bundles are submerged, be sure that the first-effect feed valve is closed and that the overflow weir pipes are set at their highest position. If the bundles are not submerged, see that the weirs are at their highest position, open the feed valves until the tube nests are fully covered, and then close the feed valves.
6. Open the valve in the emergency circulating water line from the air ejector condenser.
7. Open wide the second-effect evaporator tube nest vent valve. The first-effect tube nest vent valve should remain closed.
8. Make sure that the first-effect tube nest and the air ejector condenser drains are directed only to the bilge, and not to the ship's tanks.
9. Open the air suction to the ejector. Open the steam supply to the ejector, making sure that the full pressure required (stamped on the nameplate) is available at the nozzle, and that the steam supply is properly drained.
10. Test the salinity of the air ejector condenser drain. When less than 0.25 gpg (0.065 epm), close the bilge drain and open the drain to the tank.
11. When the second-effect shell vacuum is about 16″, open wide the first-effect tube nest steam supply valve. Adjust the regulating valve to maintain a

steady pressure of 5 psig. The last-effect shell vacuum should continue to increase to 26″ or more.

12. When the condensate discharges from the first-effect drain line to the bilge, test for salinity. When satisfactory, close the bilge drain valve, set the drain valves to discharge the condensate to the return system, and open the first-effect tube-nest vent valve, one full turn.
13. When condensate appears in the second-effect drainer, see that the drainer discharge valve is open, and then adjust the second-effect tube nest vent valve to operating position (approximately one turn open).
14. When condensate appears in the flash chamber, be sure the condensate cooler discharge is directed to the bilge by manually tripping the solenoid actuated valve. Then start the condensate pump. (The same point applies here as in 2, with reference to starting a pump.)
15. The following steps should now be performed in fairly rapid sequence:
    (a) Lower the overflow weir pipes to their operating positions.
    (b) Start the brine pump and open all valves in its discharge line.
    (c) If a loop seal of at least 8 feet has been provided in the feed line between effects, open wide the second-effect feed valve. Otherwise open it partially.
    (d) Close the emergency circulating water overboard line from the air ejector condenser and open the first-effect feed valve.
16. When the salinity of the condensate leaving the condensate cooler is less than 0.25 gpg (0.065 epm), set the solenoid valve to discharge to the ship's tanks.
17. Open and adjust the feed-treatment injection valve if feed treatment is to be done.

18. After the plant has been in operation about one-half hour, check the density of the brine. If the density is more than 1.5 thirty-seconds, open wider the first-effect feed valves; if less than 1.5 thirty-seconds, close down on the valve. Repeat every half hour until two successive readings of 1.5 thirty-seconds are obtained. Then test at hourly intervals.

Securing an Automatic Plant

THE CORRECT PROCEDURE FOR SECURING AN AUTOMATIC LOW-PRESSURE DISTILLING PLANT begins by notifying the engineer officer of the watch that the evaporator plant is ready to be secured. When permission to secure has been granted, proceed as follows:

1. Shut off the steam supply to the first-effect tube nest.
2. Close the first-effect tube-nest drain line to the return system, and open the drains to the bilge.
3. Close the first-effect tube-nest vent valve.
4. Close the air suction and steam supply valves to the air ejector.
5. Open wide the second-effect tube-nest vent valve.
6. Secure the condensate pump.
7. Raise the weir pipes, on both effects, to their highest positions and continue operation of the circulating water and brine overboard pumps for ten minutes or longer to cool off all parts of the distilling plants.
8. Secure the brine overboard pump.
9. When both tube nests are fully covered with water, secure the circulating pump.
10. Secure the suction and overboard sea chests.
11. Secure the feed valve to the first effect.
12. Close the air ejector and condenser drain lines to the return system and open the drains to the bilge.
13. Trip the solenoid valve in the condensate lines to discharge to the bilge.

Requirements for Successful Operations

The auxiliary steam supply to the first-effect tube nest should be carefully controlled to prevent exceeding the normal operating temperatures and pressures. The desirable temperatures and pressures for clean low-pressure distilling plants are indicated on the heat balance diagrams (fig. 10-14). When starting up a plant, the steam supply to the first-effect tube nest should be increased very slowly to prevent priming. Ordinarily, a condition of impure condensate will clear up rapidly if it has been due to a fluctuating operating condition. However, if it does not clear up rapidly, the plant should then be secured and each of the units tested for leakage.

Orifice Control

Capacity control is maintained by means of an orifice in the steam supply line. The orifice controls the flow of steam to the first-effect tube nest. By maintaining a constant pressure above the orifice (5 psig), the flow of steam into the tubes may be kept constant. This results in a relatively constant distilling plant output. First-effect tube nest vacuum automatically adjusts itself to provide the temperature difference required to condense the steam as fast as it enters.

Constant capacity is desirable because it provides a uniformly pure product, ease in control of water levels, and brine density.

Weight-Loaded Reducing Valves

A weight-loaded reducing valve is installed in the steam supply line to the first-effect evaporator. The purpose of this valve is to maintain the inlet steam pressure at approximately 5 psig above the orifice. To permit free movement of the valve piston, a vent is installed at the top of the valve body. During operation, this vent must be open at all times.

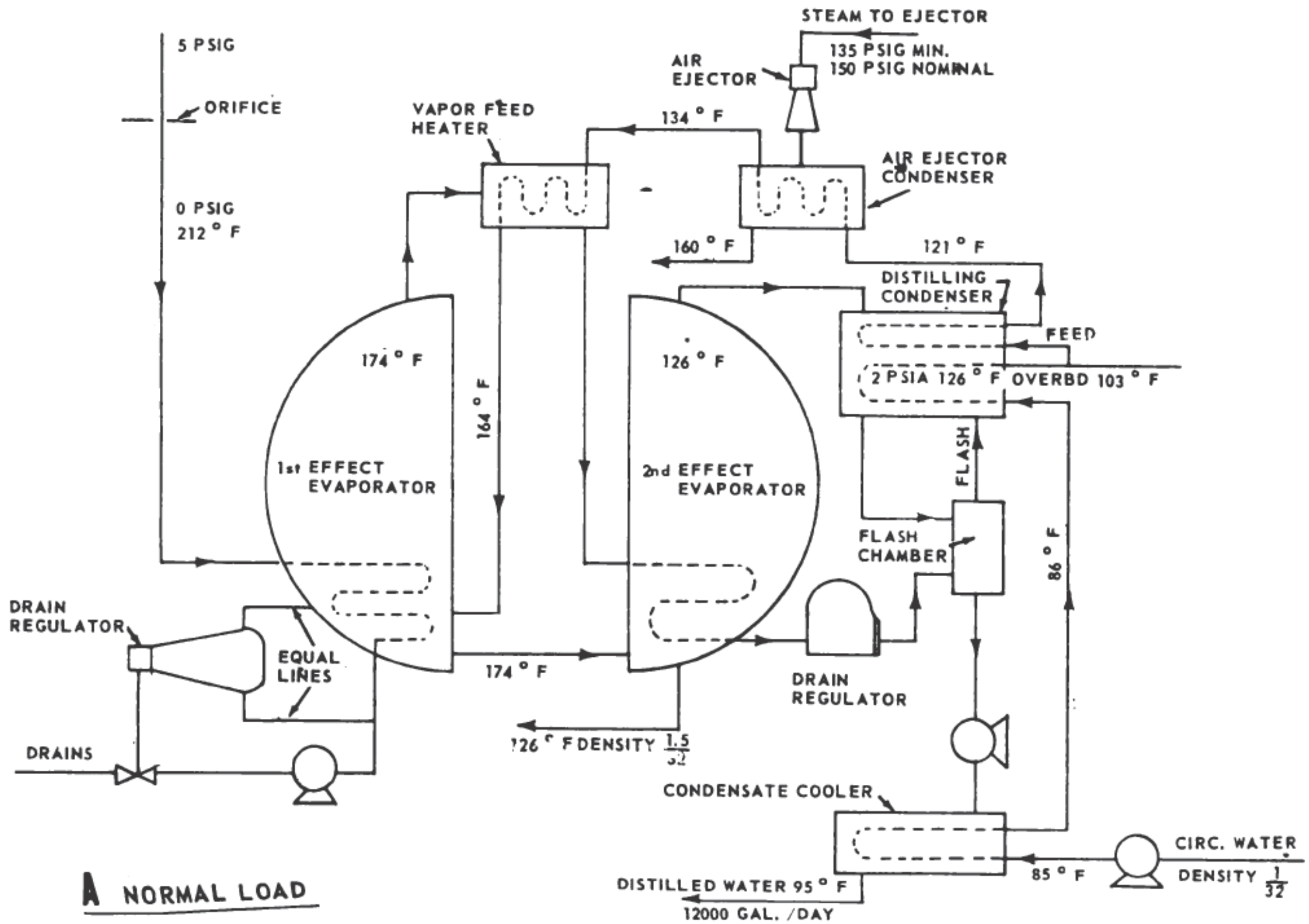


Figure 10–14.—Low-pressure distilling plant heat balance diagrams; (A) normal load.

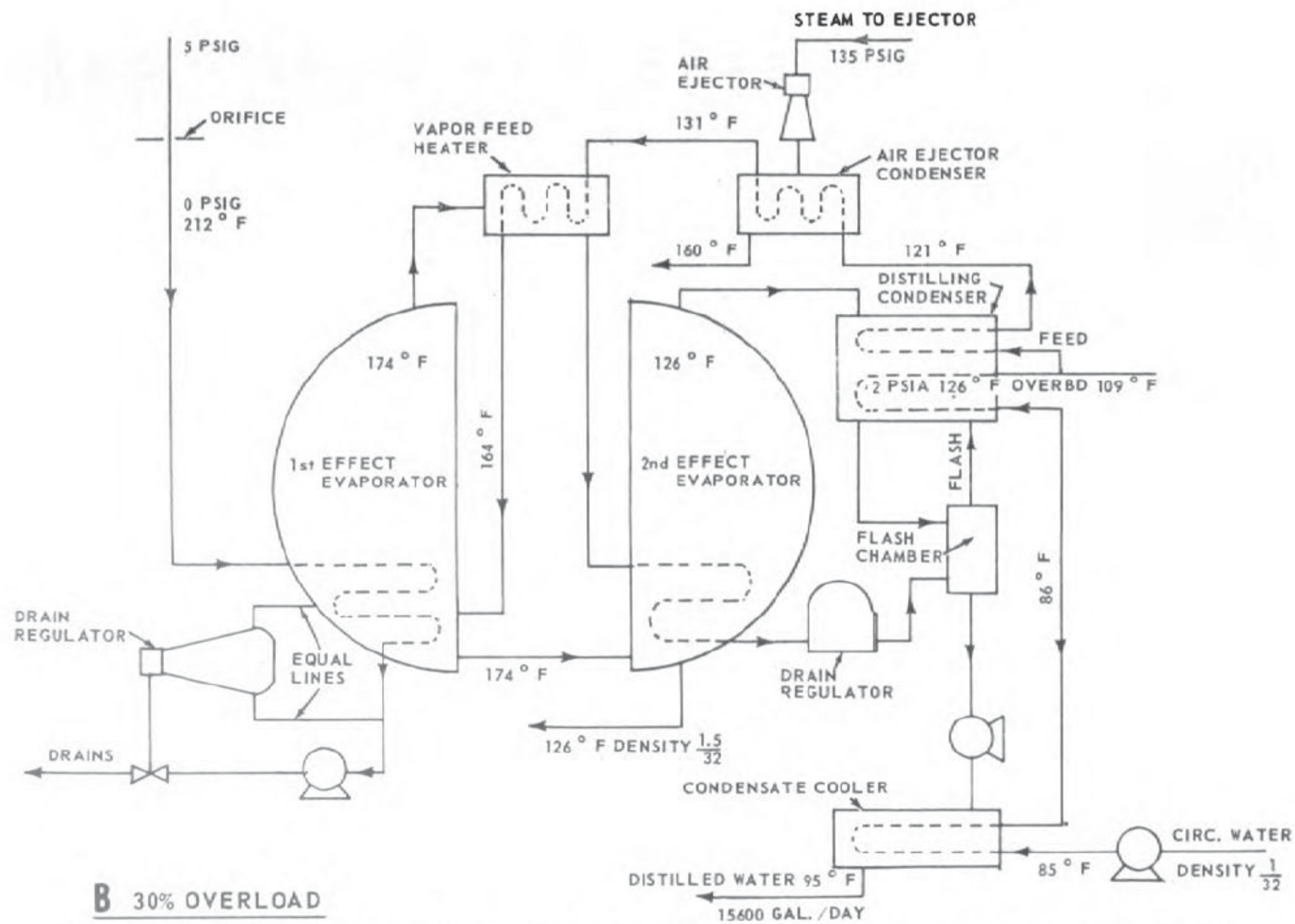


Figure 10–14.—Low-pressure distilling plant heat balance diagrams; (B) 30 percent overload.

Feed Levels

The water level in each evaporator shell can be controlled by hand-regulated feed valves or by overflow weirs. At the side of each evaporator shell you can check the level in the shell by examining the gage glass or looking through the sight glass. For most efficient evaporator operation, the tube bundles should be barely covered by the boiling brine.

Desuperheating of Steam Supply

If the steam temperature below the orifice is less than 240° F, desuperheating is unnecessary. However, if the steam temperature is between 240° and 300° F, then desuperheating below the orifice is required. Desuperheating is accomplished by taking water from the first-effect tube-nest drain pump discharge and discharging through a nozzle in the steam line between the orifice and the first-effect tube nest (fig. 10–14). The desuperheating water should never be taken from the distilling plant condensate or fresh water pump. There is likelihood of contaminating the entire boiler feed system in the event the distillate from the distilling plant becomes salty, since the first-effect coil drains are usually discharged into the deaerating feed tank.

The desuperheating connection lowers the steam temperature to the temperature corresponding to the pressure that exists in the first-effect tube bundle and which can be checked in the steam table shown on pages 392 and 393.

First-Effect Tube-Nest Vacuum

There should be no perceptible change in first-effect tube-nest vacuum in any one day's operation because of scale deposits on evaporator tubes. A sudden drop, or failure to obtain 14″ to 16″ vacuum when the tubes are clean and the plant is operated at rated capacity is due to some other cause which can and must be eliminated. Do not assume, because the distilling plant output is not

immediately affected, that the loss of first-effect tube-nest vacuum is not serious. No matter what the condition of the evaporator tubes, the first-effect tube-nest vacuum should be kept as high as possible. Otherwise more scale will form and you will have to keep the plant operating on higher temperatures. In addition, frequent cleaning will be required in order to maintain capacity.

Last-Effect Shell Vacuum

In operating the plant, it is necessary to maintain a constant last-effect shell vacuum, as a rapid fluctuation in this vacuum has a strong tendency to cause priming. It also is necessary to maintain the highest vacuum possible at all times to keep scale formation at a minimum and thus maintain capacity for long periods without cleaning.

Obtaining maximum vacuum depends upon elimination of air leaks, proper operation of air ejectors, sufficient flow of circulating water, and the effectiveness of the heat transfer surfaces in the distilling condensers.

Air Ejectors

The air ejectors require very little attention during distilling plant operations. Only one air ejector is required to maintain a vacuum of at least 26.5 inches at the air ejector suction in a tight plant.

The air ejector operating pressure stamped on the nameplate is the minimum pressure required at the nozzle. Allowance must be made for a pressure drop in the line, through the strainer when setting the air ejector steam reducing valve. A pressure at the nozzle slightly higher than the minimum specified is not objectionable unless it causes overheating of the air ejector condenser.

A low vacuum may be due to faulty operation of the ejector, but is more often due to air leakage. An unsteady vacuum, however, almost invariably indicates difficulty at the ejector. The most frequent causes are insufficient

TABLE 1.—Steam Table *

Gage Pressure	Absolute Pressure	Saturation Temperature	Gage Reading	Absolute Pressure	Saturation Temperature	Gage Reading	Absolute Pressure	Saturation Temperature
p. s. i.	*p. s. i.*	*° F.*	*Inches vacuum*	*p. s. i.*	*° F.*	*Inches vacuum*	*p. s. i.*	*° F.*
5	19.696	227	11	9.31	189.8	22¾	3.52	147.9
4	18.696	225	11½	9.06	188.6	23	3.40	146.4
3	17.696	222	12	8.81	187.3	23¼	3.28	145.0
2	16.696	219	12½	8.57	186.0	23½	3.16	143.5
1	15.696	216	13	8.32	184.6	23¾	3.03	141.9
0	14.696	212	13½	8.08	183.3	24	2.91	140.3
Inches vacuum			14	7.83	181.9	24¼	2.78	138.5
½	14.47	211.2	14½	7.58	180.4	24½	2.66	136.8
1	14.23	210.4	15	7.33	178.9	24¾	2.53	134.9
1½	13.98	209.5	15½	7.09	177.4	25	2.41	133.1
2	13.73	208.6	16	6.85	175.9	25¼	2.29	131.1
2½	13.49	207.7	16½	6.60	174.2	25½	2.17	129.1
3	13.24	206.8	17	6.35	172.5	25¾	2.05	127.0
3½	13.00	205.9	17½	6.11	170.8	26	1.93	124.7
4	12.75	204.9	18	5.86	169.0	26¼	1.81	122.3
4½	12.50	203.9	18½	5.62	167.2	26½	1.68	119.7

5	12.26	203.0	19	5.37	165.3	26¾	1.55	117.0
5½	12.01	202.0	19½	5.12	163.2	27	1.43	114.1
6	11.77	200.8	20	4.88	161.1	27¼	1.31	111.0
6½	11.52	199.7	20½	4.63	159.0	27½	1.19	107.6
7	11.27	198.9	20¾	4.51	157.9	27¾	1.067	103.9
7½	11.03	197.9	21	4.39	156.8	28	.944	99.8
8	10.78	196.8	21¼	4.26	155.5	28¼	.881	95.2
8½	10.54	195.7	21½	4.14	154.4	28½	.698	89.9
9	10.29	194.6	21¾	4.01	153.1	28¾	.575	83.9
9½	10.04	193.5	22	3.89	151.8	29	.452	76.5
10	9.80	192.4	22¼	3.77	150.5	29¼	.329	67.1
10½	9.55	191.0	22½	3.65	149.2	29½	.206	54.0

* Courtesy of Griscom-Russell

steam pressure and wet steam. A clogged strainer or nozzle may also be responsible.

Venting Evaporator Tube Nests

Proper venting of evaporator tube nests is very important. When starting a low-pressure plant, all vents leading from the steam heads to the evaporator shell should be open. When all systems of a distilling plant are operating at approximately normal temperatures and pressures, the vent valves should be adjusted so that they are open about $\frac{3}{4}$ of a turn. The amount of valve opening may vary from plant to plant; therefore, the actual setting must be determined by operating experience with a particular plant.

The result of improper venting of the evaporator tube nests may be either an accumulation of air in the tubes, with a resultant loss of capacity, or an excessive loss of tube nest steam to the distilling condenser, with a loss of efficiency.

Brine Concentration

Although the salt concentration of sea water is not always the same, the average is generally accepted as being 1 part in 32—that is, 1 pound of dissolved salts is contained in 32 pounds of sea water. As sea water is vaporized in the distilling plant, the proportion of dissolved salts becomes greater in the remaining solution. The brine concentration in the last-effect shell should be kept at 1.5 thirty-seconds—that is, there are 1.5 pounds of dissolved salts in 32 pounds of brine.

The concentration of brine in the evaporator, within limits, has a direct bearing on the quality of the fresh water distilled by the plant. Since the varying quantities of brine that are discharged overboard affect the operating conditions of the plant, it is desirable to keep the quantity of brine discharged and the brine concentration in the last-effect shell as constant as possible. If the brine

concentration is too low, there will be a loss in capacity and economy, and it will be difficult to obtain proper feeding. If the brine concentration is too high, there will be an increase in the rate of scaling of the evaporator tubes, and the quality of the distillate may be impaired. The brine concentration depends mainly on the quantity of brine pumped overboard and the quantity of fresh water being produced. The brine concentration should be checked frequently during each watch (usually at intervals of 1 hour) by means of a salinometer. The brine concentration should then be adjusted to 1.5 thirty-seconds (it should never exceed this amount) by means of the hand-control valve located in the brine overboard pump discharge line. Care should be taken in opening or closing this valve, as very small changes in its opening will cause the brine concentration to vary greatly.

Cleanliness of Heat Exchange Surfaces

The output of the low-pressure distilling plant is not reduced appreciably by scale deposits on the evaporator tubes until the deposits have caused a reduction in first-effect tube nest vacuum to 1 or 2 inches. When the first-effect tube nest vacuum is lost entirely, the reduction in output becomes very great. Assuming the reduction in vacuum is due to scale, and is not the result of improper operating conditions, the evaporator tubes must be cleaned when the tube nest vacuum approaches zero. When the plant is properly operated, and when the evaporator feed is treated, the interval between cleanings should be six months or more.

Salt water flows inside the distilling condenser tubes, air ejector condenser, and vapor feed heaters. Under some operating conditions, scale deposits may accumulate inside these tubes, particularly in the air ejector condenser and first-effect feed heater. Every six months, or whenever the plant is secured for descaling evaporator tubes, the inside surfaces of these heat exchanger tubes should

be inspected and cleaned if necessary. Neglect can lead to thick scale deposits which will then be difficult to remove.

SCALE FORMATION AND PREVENTION

With proper feed-water distribution, steam pressure above the orifice at not over 5 psi, a high vacuum, and the brine overboard concentration not over 1.5 thirty-seconds, very little hard scale should form in the distilling plant, when sea water is used for feeding the evaporator.

During normal operating conditions, scale deposits will form at a certain rate on the distilling plant evaporator tubes. The rate of scaling depends upon the concentration of suspended matter and carbonate salts present in the sea or fresh water used to feed the distilling plant. However, the important point to remember is that excessive scaling of the evaporator tubes can be caused by improper operation of the distilling plant.

The scale deposits increase as the density of the brine in the last-effect shell increases. The brine concentration is dependent mainly upon the quantity of brine pumped overboard and upon the amount of fresh water produced. If the brine concentration is too high, there will be an increase in the rate of scaling of the evaporator tubes, and the quality of the distillate may be impaired.

To retard the formation of scale on evaporator tubes, a solution of boiler compound and cornstarch is continuously introduced into the evaporators. The purpose of the cornstarch is to minimize priming, and the boiler compound combats tube scaling. If the feed treatment is used, daily chill-shocking may be desirable; however, longer intervals are satisfactory.

Chill Shocking

The first-effect tube nest, in which the temperature of the tube nest is near that of the steam supply, tends to scale up more quickly than other parts of the plant. To combat this scale, some method of CHILL SHOCKING the

tubes is generally provided. This is done by draining the brine from all shells, then reflooding them by means of a hose line connected to a flushing pipe or flooding connection on the shell. This chills the tube nest bundles. Steam is then quickly admitted into the tubes, causing differential expansion and contraction to take place, which breaks the scale loose from the tubes.

If the cornstarch-boiler compound feed treatment is not used, the distilling plant should be chill shocked daily. If the feed treatment is used, daily chill shocking may be desirable; however, longer intervals are satisfactory.

Chill shocking is performed as follows:

1. Secure the steam supply to the first-effect tube nest, the tube nest drain pump and its discharge valve, the condensate pump, and the fresh water pump.
2. Open the emergency circulating water overboard valve at the outlet from the air ejector condenser and secure the first-effect feed valve.
3. Open wide all interstage feed valves. In plants which have shell drain or pump-out lines connected to the brine pump suction, unlock and open wide the valves in these lines.
4. Pump out the brine from all evaporator shells.
5. Connect a hose line to the flushing pipe or flooding connection.
6. Open the hose (water supply) valve to spray or flood the evaporator shells until the tubes in all evaporator shells are fully submerged.
7. Secure the hose valve and again pump out all evaporator shells.
8. Flood all shells again until the tubes in all shells are submerged. This second flooding is to lower the tube bundle temperature as much as possible. When the tubes are fully submerged, secure the hose valve and open quickly the steam supply valve to the first-effect tube nest. The flow of steam will be restricted somewhat by the orifice, if installed,

and should be increased by loading the weight-loaded regulating valve to produce not more than 10 psig pressure above the orifice. After the plant has warmed up, the pressure should be cut back to normal.

9. Start the pumps and regulate the water levels as necessary to put the plant in steady operation.
10. If the plant is one of the earlier installations which have chill shocking and spraying water supply from the fire and flushing main, disconnect the hose line from the flooding or flushing connection to protect the evaporator shells from possible excessive pressure.

After chill shocking, and about once a week, remove the hand-hole plates on the bottom of the evaporator shells and rake out the scale which has flaked off the tubes.

LATEST DESIGNS IN EVAPORATORS

Some of the newer ships in the Navy are being equipped with evaporators which differ radically from the more familiar low-pressure submerged-tube type evaporator previously discussed. There are two types of these low-pressure evaporators: the vertical-basket type and the flash type.

Low-Pressure Vertical-Basket Type

The low-pressure vertical-basket type distilling plant (fig. 10–15A) consists of two-effect (or more) evaporators with a distiller condenser, vapor feed heaters, air ejectors and after condensers, and a distillate cooler. The only difference between this type of distilling plant and the conventional submerged-tube type is in the evaporators. Each evaporator consists of a vertical shell into which a deeply corrugated vertical basket is installed. See Fig. 10–15B. In some installations more than one basket may be installed. Low-pressure steam is admitted to the inside of the first-effect basket and feed water is boiled in the

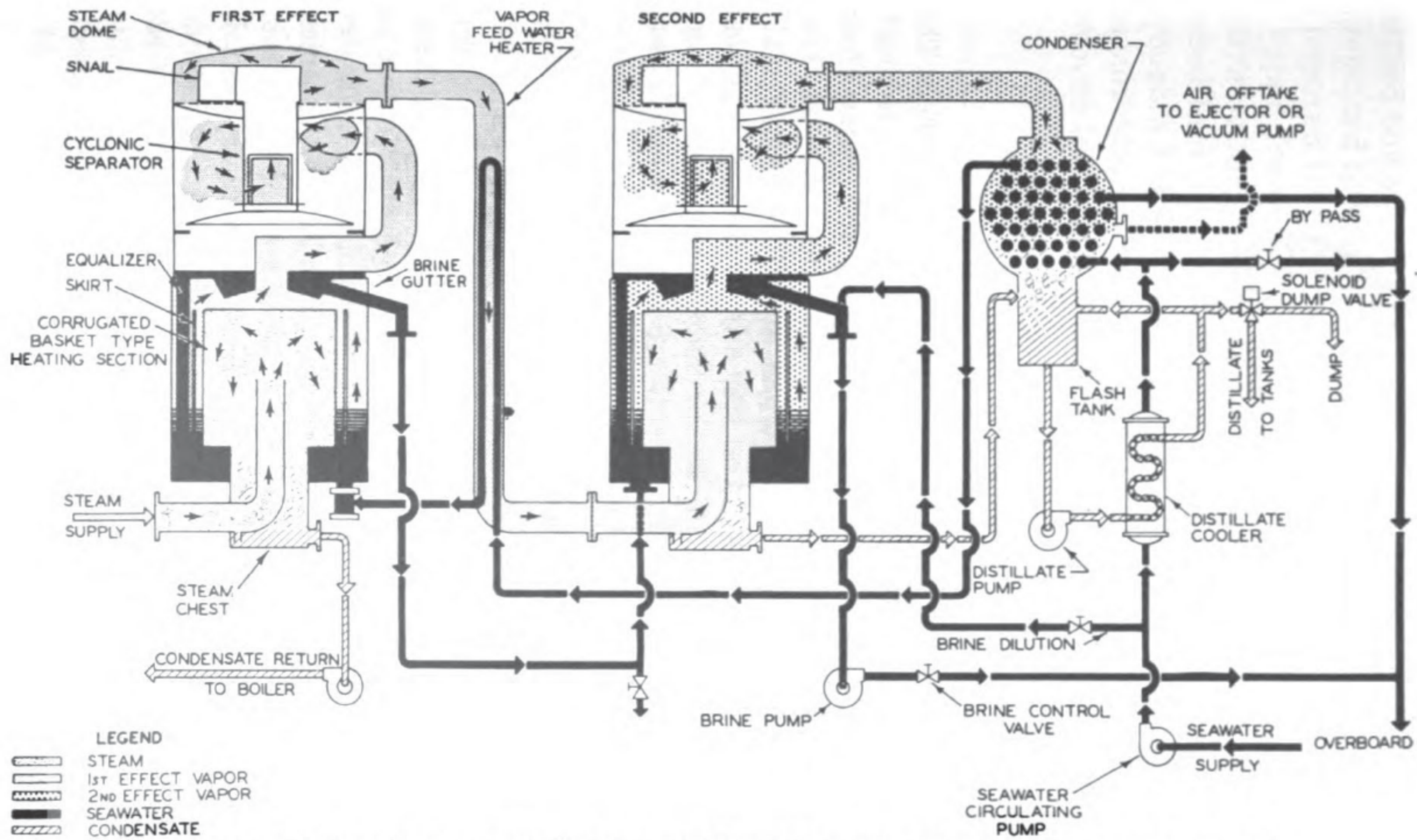


Figure 10–15.—(A) Low-pressure, double-effect distilling plant with vertical basket-type evaporators.

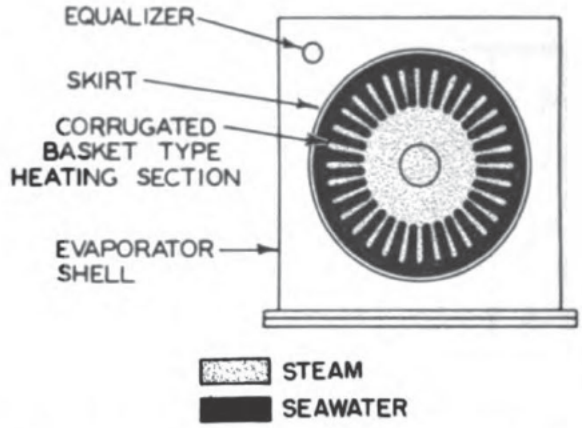


Figure 10–15.—(B) Section view of evaporator.

space between the outside of the basket and the shell. The vapor formed from the boiling feed water passes through centrifugal-type vapor separators and the vapor feed heater into the inside of the second-effect basket. This boils the brine from the first-effect in addition to a certain amount of feed water in the space between the shell and the basket. The vapor thus formed passes through separators to the subsequent effects, or in the case of a two-effect basket, into the distiller condenser.

Low-Pressure Flash Type

The low-pressure flash type distilling plant consists of two or more stages, each stage composed of a flash chamber, a feed box, a vapor separator, and a stage condenser. In addition, there is a two- or three-stage air ejector, an after condenser, and a feed water heater. The feed water passes through the tubes of the stage condensers in series, then through the tubes of the after condenser, and those of the feed water heater. In each heat exchanger, heat is transferred to the feed water and the final heating is done by low-pressure steam admitted to the shell of the feed-water heater. From this heater the feed water is passed to the first-stage feed box and comes out through orifices into the flash chamber. Part of the heated feed water flashes to vapor under the vacuum in the flash chamber. The re-

mainder of the feed water passes through a loop seal to the feed box of the subsequent stage. This flashing process is repeated in subsequent stages and the remaining brine is removed by the brine overboard pump.

Vapor formed in each stage passes through a vapor separator and into the stage condenser where it is condensed to distillate. The distillate from each stage passes through a loop seal on its way to the condenser of a subsequent stage. From the final stage, the distillate is removed by the distillate pump.

Cold Shocking

Scale forms on the outside of the corrugations of the vertical basket-type evaporator. The scale can be removed by cold shocking. Drain the shell and admit low-pressure steam into the basket. This expands the corrugations and also dries the scale, thus making the scale brittle. Turn off the steam and admit sea water into the shell until the basket is covered by the sea water. Condensation of the steam in the basket creates a vacuum and the differential pressure causes the corrugations to contract. This loosens the scale which drops to the bottom of the shell. Clean-out holes near the bottom of the shell can be opened for removal of the scale particles.

The first effect, which has the most scale formation, is usually cold shocked about every 75 hours. Subsequent effects should be cold shocked at double this interval or more. In the case of the quadruple effect unit, the fourth effect will probably require cold shocking only once or twice a year.

In the flash-type evaporator, scale formation is reduced to a minimum and occurs only in the feed water heater tubes. This reduced scale formation is due to the fact that the feed is heated under pressure, which prevents boiling, and vapor is formed by free flashing under vacuum.

For further information about these two new type evaporators, refer to the manufacturer's instruction

books: NavShips 358–0307 for low-pressure vertical-basket type evaporators and NavShips 358–0324 (which is in the preliminary stage of preparation) for the low-pressure flash-type evaporator.

DISTILLATE TESTING

The fresh water (distillate) produced must meet specified standards of chloride content and purity. To ensure that those standards are met, the distillate must be tested continuously. Chloride content and purity tests are accomplished by two methods: the electrical salinity test and the periodic chemical tests.

The results of feed water tests are expressed in terms of a unit called EQUIVALENTS PER MILLION (epm). However, before explaining epm, it will be easier if you understand a unit called PARTS PER MILLION (ppm).

PARTS PER MILLION is a weight-per-weight unit denoting the number of parts of a specified substance in a million parts of water. For example, 58.5 pounds of salt in 1 million pounds of water represents a concentration of 58.5 parts per million (ppm). Note, also, that 58.5 OUNCES of salt dissolved in 1 million OUNCES of water, or 58.5 TONS of salt dissolved in 1 million TONS of water represent the same concentration—that is 58.5 ppm.

EQUIVALENTS PER MILLION can be defined as the number of equivalent parts of a substance per million parts of water. (The word "equivalent" here refers to the chemical equivalent weight of a substance.) The chemical equivalent weight is different for each element or compound. The chemical equivalent weight of sodium chloride (common table salt) is 58.5. A solution containing 58.5 PARTS PER MILLION of this salt is said to contain 1 EQUIVALENT PER MILLION. If a substance has a chemical equivalent of 35.5, a solution containing 35.5 ppm is described as having a concentration of 1 epm.

The chloride content of a distillate turned into the reserve feed tanks must not be greater than 0.12 epm.

Distillate turned into the ship's service or potable water tanks must not have a chloride content above 0.065 epm—just half as much as the limit established for boiler water. The Bureau of Medicine and Surgery requires that this low chloride content now be maintained. The former allowable limit of 0.261 epm (1.0 grain per gallon) still retained harmful bacteria in the distillate.

Electrical Salinity Indicators

Electrical salinity indicators are installed throughout the distilling plant to maintain a constant check on the distilled water. An electrical salinity indicator consists of a number of electric salinity cells in various points in the plant: in the fresh-water pump discharge, distiller condensate pump discharge, tube-nest drain, air ejector condenser drain, etc., and connected to a salinity indicator panel on a bulkhead near the plant.

Since the electrical resistance of a solution varies according to the amount of ionized salts in solution, it is possible to measure salinity by measuring the electrical resistance. The salinity indicator panel is equipped with an ammeter calibrated to read directly in either epm or grains per gallon (gpg). Since resistance also varies with temperature, a temperature-compensator must be set at a value corresponding to the temperature of the solution.

When reading the dial of an electrical salinity indicator, be sure that you know what you're reading. Some salinity indicators are still calibrated in grains of sea salt per gallon. This unit is no longer used for reporting water analyses, so any reading taken in gpg must be converted to epm. Multiply the gpg (meter reading) by 0.261 to get the chloride epm. For example, a meter reading of 0.75 grains of sea salt per gallon is equal to 0.75×0.261, or 0.195 epm chloride.

To check an electrical salinity indicator for operation, proceed as follows:

1. Turn on the power to the indicator.
2. Set the temperature-compensator at 110° F.

3. Depress the test button and hold it down until the reading is taken.
4. Read the indicator. The reading should be approximately 1 grain. If the salinity indicator does not give a reading of 1 grain, the instrument is not correctly calibrated and should be checked by an I. C. Electrician.

Chemical Salinity Testing

A chemical salinity testing procedure must also be followed for every 50 gallons of distillate pumped into the measuring and testing tanks of the plant. This test is applied to samples of water drawn out through the test cocks of the tanks. Specific instructions for making the tests are generally posted on or near the water testing equipment cabinet provided in each evaporator space. The instructions may also be found in chapter 56 of the *Bureau of Ships Manual.* The general procedure is as follows:

1. Fill the 100-ml graduated cylinder with a distillate sample from the test tank and pour it into a clean, dry casserole.
2. Add 5 drops of chloride indicator to the sample. The water should turn blue-violet or red, depending upon its alkalinity.
3. Using the nitric acid burette, add reagent nitric acid, one drop at a time, stirring continuously, until the violet or red color just disappears. (The water will probably be pale yellow.)
4. Now add exactly 1 ml more of reagent nitric acid.
5. Fill the mercuric nitrate burette and let it drain down to zero. Drain some to fill the burette to the tip. Then refill the burette.
6. Place the casserole under the mercuric nitrate burette and add reagent mercuric nitrate to the contents of the casserole. Stir continuously until a pale blue-violet color persists throughout the solution. (Add the mercuric nitrate at a fairly rapid rate at

first, but add it very slowly—drop by drop—as the end point is approached.)

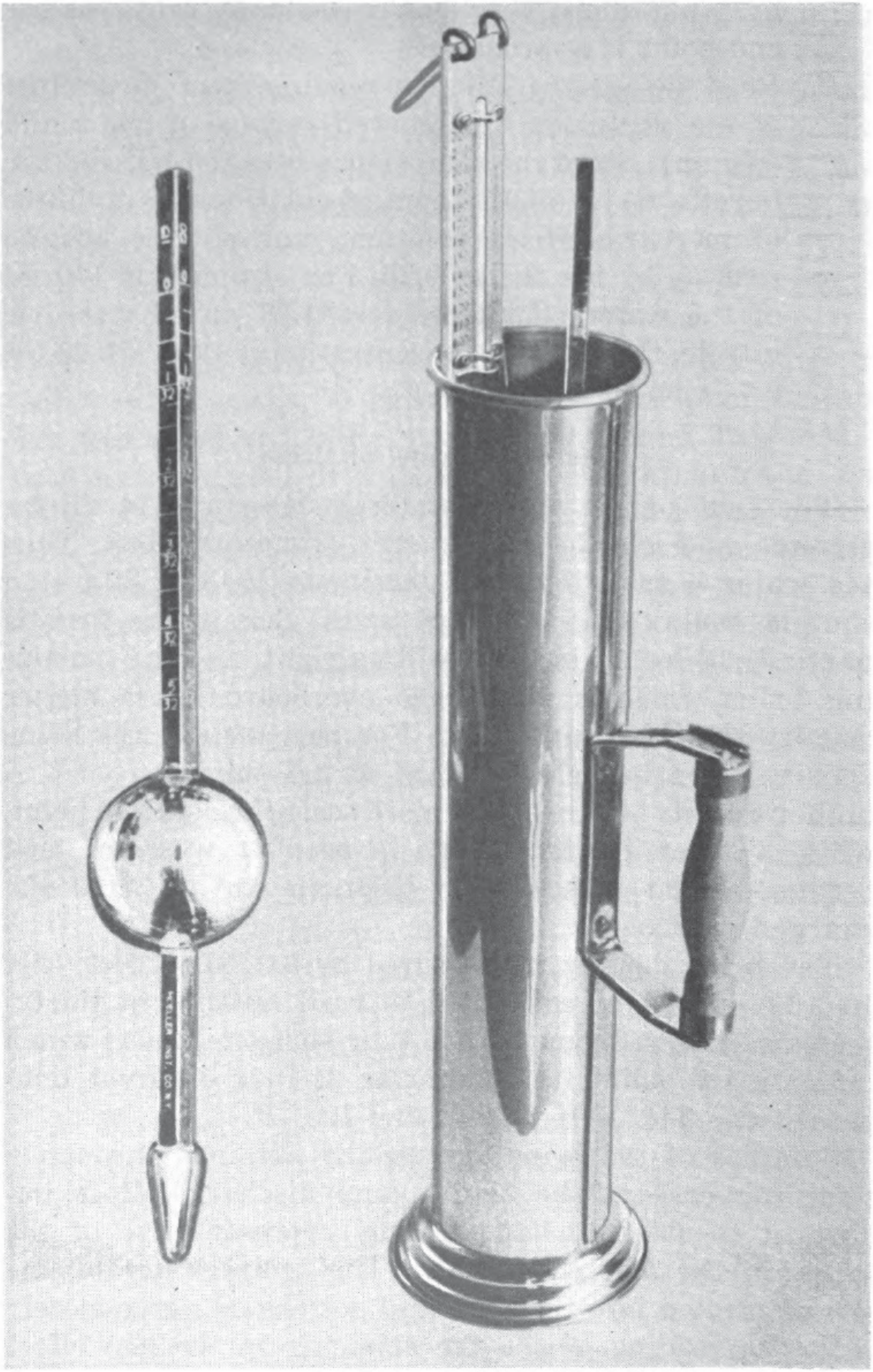
7. Read the burette. Take the reading from the BOTTOM of the MENISCUS (the curved surface of the liquid column). Since the sample size was 100 ml, and the burette factor is 0.25 epm of chloride per milliliter of mercuric-nitrate solution, multiply the burette reading by the factor 0.25. For example, if 100 ml of the water sample require 1.75 ml of mercuric nitrate, the chloride concentration is 1.75×0.25, or 0.44 epm.

Testing Density of Brine

The salt content of sea water is measured in thirty-seconds, and is called its DENSITY (concentration). Thus sea water is said to have a density of $\frac{1}{32}$ if a 32-pound sample contains 1 pound of salts. Sea water feed is partially boiled off in the distilling plant, and the remaining brine which is discharged overboard has a higher density than the initial feed. For best results, the brine density must be held constant at 1.5 thirty-seconds. A higher density will result in more scale through the plant, while a lower density results in needless waste of heat because of the unnecessarily large amount of brine discharged overboard.

The brine density is measured by SALINOMETERS (fig. 10–16) which are calibrated to read directly in thirty-seconds. The salinometer has four separate scales which indicate the salinity of the brine at four different temperatures—110°, 115°, 120°, and 125° F.

Samples of the brine are usually obtained through a sampling cock at the brine pump discharge. It is important to obtain a sample truly representative of the brine in the last effect shell. The temperature of the sample drawn into the sampling pot should agree closely with the reading of the thermometer on the last effect shell. A difference of more than 3° or 4° F usually indicates faulty operation of the brine pump, or dilution of



Courtesy of Moeller Instrument Company

Figure 10–16.—Salinometer and sampling pot.

the brine between the last effect shell and the sampling cock.

Feed Water Treatment

The evaporator feed water is treated with a solution of cornstarch and boiler compound. The purpose of cornstarch is to minimize priming, and the purpose of the boiler compound is to reduce tube scaling.

A MIXING TANK, provided with steam and filling water connections, is used to mix and boil the cornstarch, boiler compound, and water. This tank will vary in size, depending on the size of the distilling plant. The mixture is drained from the mixing tank into the SUPPLY TANK, which is equipped with a steam heating coil for keeping the mixture warm. The supply tank has a calibrated gage glass which is used to determine the rate at which the solution is fed to the evaporator. The solution is drawn into the first-effect shell by the shell vacuum, through a hand-controlled valve in the line from the supply tank. Table 2 may serve as a guide in mixing and using the cornstarch boiler compound solution for feed treatment.

TABLE 2.—CORNSTARCH BOILER COMPOUND SOLUTION

Nominal capacity of distilling plant	Quantities of solution for each batch mixed*	Recommended tank capacity as calibrated on gage glasses		Rate of feed for solution	Suggested treatment in each batch* mixed	
		Mixing tank	Supply tank		Corn-starch	Boiler comp.
Gal. per day	*Gal.*	*Gal.*	*Gal.*	*Gal. per hr.*	*Oz.*	*Oz.*
4,000	4	5	10	⅔	2	4
8,000	8	10	20	1⅓	4	8
10,000	10	10	30	1⅔	5	10
12,000	12	10	30	2	6	12
20,000	20	20	50	3⅓	10	20
30,000	30	30	75	5	15	30
40,000	40	40	100	6⅔	20	40

* Each batch is a 6-hour supply.

The cornstarch boiler compound solution should be mixed as follows:

1. Fill the mixing tank with one-half of the water required for a batch. Fresh water at a temperature not warmer than 100° F should be used.
2. Slowly sift dry starch into the water, stirring continuously so as to avoid lumps. (See table for proper amount of starch to be used for each type of plant.)
3. When the starch is dissolved, add the boiler compound in the amount prescribed (see table). Mix thoroughly and bring to a boil by admitting steam, and continue boiling and stirring from 10 to 15 minutes.
4. Discharge the mixture through a strainer into the supply tank, then add the other half of the water required to make the patch.

   (The solution is now ready to be discharged into the evaporator. The table gives the rate of feed for the different sizes of distilling plants.)
5. Not more than a 12-hour supply should be prepared at any one time.
6. The mixing tank should be thoroughly cleaned after use.

Injecting Cornstarch-Boiler Compound Solution Into Evaporators

The cornstarch and boiler compound will settle on the bottom of the supply tank unless the solution is stirred frequently. If the starch and boiler compound are properly dissolved in the mixing tank, and if the solution is stirred continuously in the supply tank, the solution may be allowed to cool gradually between batches. Otherwise, occasional steam heating may be required.

The solution should be injected into the first-effect evaporator continuously and at a constant rate through a perforated pipe. The rate of feed for the solution is given in column 4 of table 2.

Once a week the supply tank should be emptied, scrubbed thoroughly, and all adhering crusts or lumps scraped off. Then fill the supply tank with water which has been preheated to boiling in the mixing tank. The filled supply tank should be boiled for 20 minutes to sterilize the supply tank. After 20 minutes of boiling, the water should be drained and the supply tank restored to service.

LOW-PRESSURE DISTILLING PLANT OPERATING RECORD

The Distilling Plant Operating Record (figs. 10–17 and 10–18) is a daily record of the operation of the ship's evaporators and their auxiliaries. Entries are made for each hour of the watch while the distilling plants are in operation. Different ships have different types of distilling plants, but all of the daily distilling plant operating records require practically the same data. The record form illustrated is used primarily for Soloshell evaporators on destroyers and destroyer escorts.

The information required by this record consists of the following:

1. Feed-water injection temperature.
2. Auxiliary exhaust steam pressure to the reducing valve or orifice.
3. Coil pressure, coil-drain temperature, shell vacuum, and feed-water temperature for each evaporator effect unit.
4. Steam inlet pressure, suction temperature, and suction vacuum of the air ejector for each evaporator unit.
5. Distillate circulating pump discharge pressure and temperature for each evaporator unit.
6. Brine temperature and density (32ds) through the brine pump of each evaporator unit.
7. Meter reading for flow of fresh water distillate, quantity of distilled water produced, both chemical and electrical salinity measurement of the distilled

NAVSHIPS 3610 REV. 11-48

LOW PRESSURE DISTILLING PLANT OPERATING RECORD

UNDERWAY X AT ANCHOR

U.S.S. FROST - CVA 999 PLANT NO. 1

TIME: ZONE DESCRIPTION PLUS 4 SET CLOCKS AHEAD OR BACK MINUTES AT DATE 10 JANUARY 19 56

HOUR ENDING

STEAM TO RED. VALVE, PRESSURE #G	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15					15	15	15	15	15
STEAM FROM RED. VALVE, PRESSURE #G	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5					5	5	5	5	5
STEAM TO 1ST EFFECT, PRESSURE, "HG OR #G	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5					5	5	5	5	5
STEAM TO 1ST EFFECT, TEMPERATURE, °F	227	227	227	227	227	227	227	227	227	227	227	227	227	227	227					227	227	227	217	227
1ST EFFECT COIL DRAIN, TEMPERATURE, °F	212	212	212	212	212	212	212	212	212	212	212	212	212	212	212					212	212	212	212	212
1ST EFFECT SHELL PRESSURE, "HG	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16					16	16	16	16	16
2D EFFECT COIL DRAIN, TEMPERATURE, °F	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180					180	180	180	180	180
2D EFFECT SHELL PRESSURE, "HG	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22					22	22	22	22	22
3D EFFECT COIL DRAIN, TEMPERATURE, °F	135	135	135	135	135	125	125	135	135	135	135	135	135	135	135					135	135	135	135	135
3D EFFECT SHELL PRESSURE, "HG	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26					26	26	26	26	26
CONDENSATE TO COOLER, TEMPERATURE, °F	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110					110	110	110	110	110
CONDENSATE FROM COOLER, TEMPERATURE, °F	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95					95	95	95	95	95
BRINE OVERBOARD, TEMPERATURE, °F	125	125	125	125	125	125	125	125	125	125	125	125	125	125	125					125	125	125	125	125
STEAM TO AIR EJECTOR, PRESSURE, #G	135	138	138	140	140	140	140	138	138	137	138	140	140	137	137					140	138	139	140	139
AIR EJECTOR DRAINS, TEMPERATURE, °F																								
CIRC. WATER INJECTION, TEMPERATURE, °F	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85					85	85	85	85	85
CIRC. WATER TO CONDENSATE COOLER, TEMPERATURE, °F	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85					85	85	85	85	85
CIRC. WATER TO DISTILLER CONDENSER, TEMPERATURE, °F	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87					87	87	87	87	87
FEED TO AIR EJECTOR CONDENSER, TEMPERATURE, °F	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121					121	121	121	121	121
FEED TO 3D EFFECT VAP. FD. HEATER, TEMPERATURE, °F	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132					132	132	132	132	132
FEED TO 1ST EFFECT VAP. FD. HEATER, TEMPERATURE, °F	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153					153	153	153	153	153
FEED TO 1ST EFFECT, TEMPERATURE, °F	177	177	177	177	177	177	177	177	177	177	177	177	177	177	177					177	177	177	177	177
CIRC. WATER OVERBOARD, TEMPERATURE, °F	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108					108	108	108	108	108
CIRC. PUMP SUCTION PRESSURE, #G	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5					5	5	5	5	5
CIRC. PUMP DISCHARGE PRESSURE, #G	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22					22	22	22	22	22
BRINE PUMP SUCTION PRESSURE, #G																								
BRINE PUMP DISCHARGE PRESSURE, #G																								
FEED PUMP SUCTION PRESSURE, #G																								
FEED PUMP DISCHARGE PRESSURE, #G																								
1ST EFFECT DRAIN PUMP SUCTION PRESSURE, #G	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5					5	5	5	5	5
1ST EFFECT DRAIN PUMP DISCHARGE PRESSURE, #G	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25					25	25	25	25	25
F. W. PUMP DISCHARGE PRESSURE	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75					75	75	75	75	75
FEED DENSITY, 32NDS	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32					1/32	1/32	1/32	1/32	1/32
BRINE OVERBOARD DENSITY, 32NDS	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32	1.5/32					1.5/32	1.5/32	1.5/32	1.5/32	1.5/32
AIR EJECTOR DRAINS, SALINITY—E.P.M.	.025	.025	.025	.025	.025	.025	.025	.025	.025	.025	.025	.025	.025	.025	.025					.025	.025	.025	.025	.025
1ST EFFECT DRAINS, SALINITY—E.P.M.	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02					.02	.02	.02	.02	.02
CONDENSATE FROM COOLER, SALINITY—E.P.M.	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02					.02	.02	.02	.02	.02

Figure 10-17.—Low-pressure distilling plant operating record: data page.

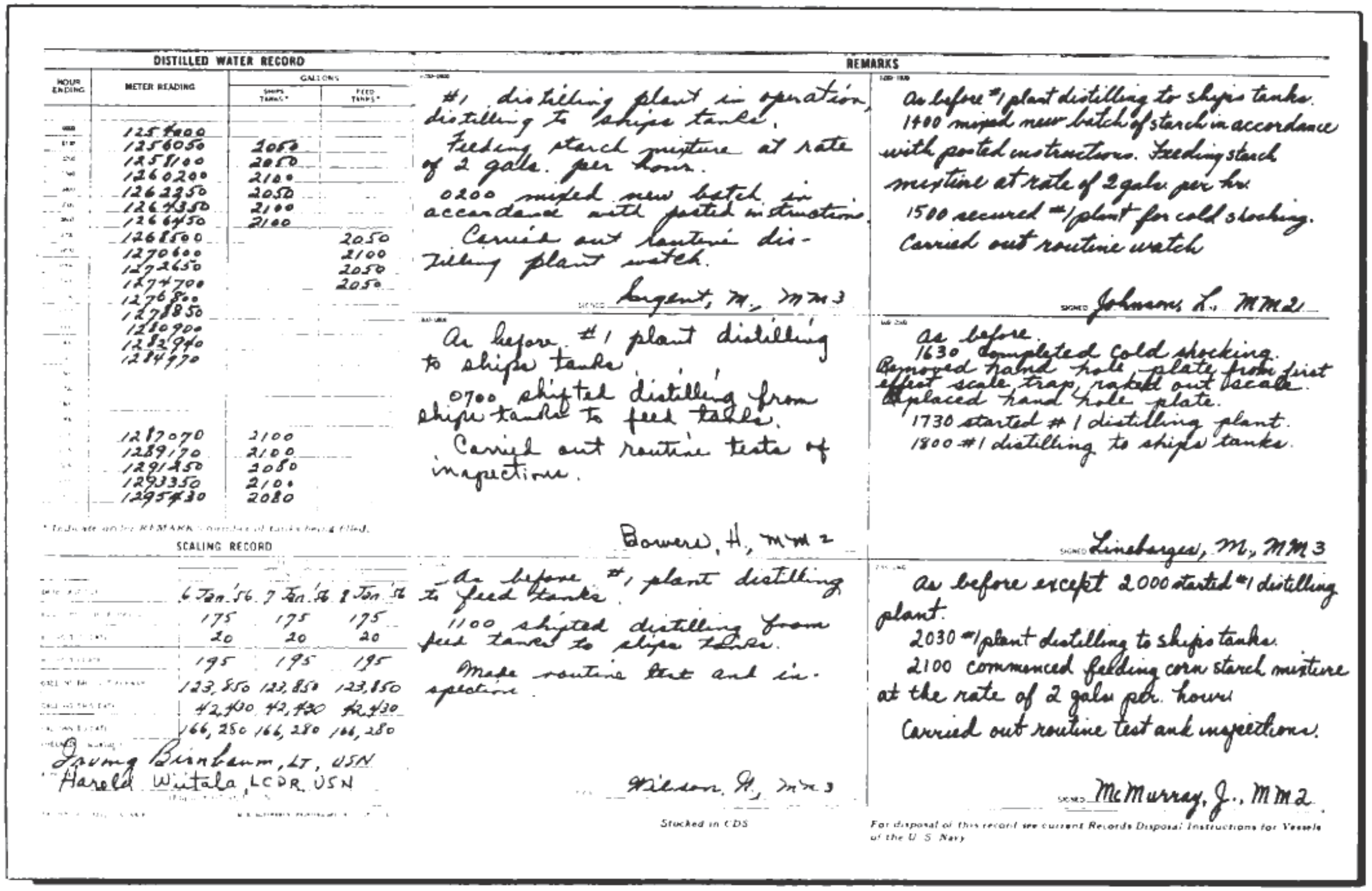


Figure 10-18.—Low-pressure distilling plant operating record: remarks page.

water, and whether the water was piped to the ship's tanks or the feed bottoms.

8. Scaling record for each evaporator unit, which includes the date of last scaling, and the hours operated and the quantity of distilled water produced since the last scaling to the day of record, on the day of record, and since the last scaling to the end of the day of record.
9. Time of starting and securing and the total operating time for the day for each evaporator and each unit of auxiliary machinery, including air ejectors, distillate circulating pumps, brine pumps, feed-water pumps, fresh-water pumps, and coil-drain pumps.
10. Remarks (fig. 10–18) concerning the distilling plant operation and maintenance for each watch of the day.

It is absolutely essential that you make accurate entries in the Distilling Plant Operating Record. During your watch, the distilling plant may suddenly develop some trouble which you may be unable to diagnose. However, if accurate entries were made previously in the record, you may get a lead to the possible trouble by reading the previous entries.

CARE AND MAINTENANCE OF THE PLANT

The full output of a distilling plant can be maintained for relatively long periods without interruption only if every part of the plant is kept in proper operating condition. This can be ensured by periodic tests, inspections, and cleaning or replacing parts as necessary. Some parts will require more attention than others.

Care of Strainers

Quick-opening, flanged, basket type strainers are installed in the suction lines of the brine pump and circulating pump to prevent foreign matter from entering the pumps and piping systems of the distilling plant.

The brine pump suction strainer should be inspected DAILY and a clean one installed if necessary. The clogging of this strainer interferes with the operation of the pump, and makes it impossible to maintain the brine density at 1.5 thirty-seconds.

The circulating pump suction strainer should be inspected about once a week when at sea, and more frequently when in port. Even partial clogging of this strainer will result in a reduction in the flow of circulating water, which in turn causes a reduced vacuum. Scale will then form more rapidly on the evaporator tubes and inside the vapor feed heater and air ejector condenser tubes.

Air Ejector Cleaning

The AIR EJECTOR STEAM STRAINER should be inspected regularly and cleaned whenever necessary. When a new plant is put into operation, the strainer may require cleaning daily or even more frequently, due to the foreign material in the new lines. Once the steam lines have been thoroughly flushed out, a monthly check should be satisfactory. Failure to keep the strainer clean will cause a reduced and fluctuating vacuum.

Clogging or scoring of the air ejector NOZZLE can also cause a reduced or fluctuating vacuum. The nozzle can be cleaned, in place, by a special reamer provided for that purpose. The reamer is turned by hand, exerting a moderate pressure. A scored nozzle must be replaced with a new one.

Scaling the Tubes

The capacity of a distilling plant is not appreciably reduced by scale deposits on the EVAPORATOR TUBES until the deposits have caused the first-effect vacuum to be reduced to 1 or 2 in Hg. When scale deposits cause the vacuum to approach zero, the tubes must be cleaned to keep the plant operating at its maximum efficiency. When the plant is properly operated and the feed water is

treated, the interval between cleanings should be about six months. The evaporator tube nest must be withdrawn from the shell for the cleaning. Lifting gear suitable to the type of installation is usually provided to facilitate removing the tube nest.

Some installations are provided with an overhead trolley from which the tube nest may be suspended for cleaning. Another type is provided with tracks and roller brackets which bolt to the front head of the tube nest. Chain falls can be used to handle the tube nest in small installations.

When the tube nest is withdrawn beyond the support plate, the tube-nest stop should be bolted in place to prevent accidental dropping of the rear head. The tubes are cleaned with a light scaling tool operated by a light air hammer. It should be held against the tube with moderate pressure, and moved over the entire length of the tube. Every tube in the nest must be cleaned, as missing one will impair the output of the plant and also make cleaning more difficult in the future.

A torch should never be used for descaling a tube nest made up of straight tubes. The expansion and contraction caused by the heat may cause the tubes to loosen at their joints.

After cleaning the tubes, a hydrostatic test of 50 psi should be applied to the bundle before replacing it within the shell.

When the evaporator tubes are pulled for cleaning, the DISTILLING CONDENSER, AIR EJECTOR CONDENSER, and the VAPOR FEED HEATERS should be inspected and cleaned, if necessary. Under some operating conditions, scale deposits may accumulate in these tubes, particularly in the air ejector condenser and the first-effect feed heater.

The distilling condenser on Soloshell end pull plants must be removed for inspection and cleaning. On other types of plants the distilling condenser can be inspected and cleaned by removing the heads at both ends. The air ejector condensers on all plants can be cleaned by re-

moving both heads. The vapor feed heater tubes on practically all designs must be removed for cleaning.

The cleaning of these tube nests is accomplished by means of an extended shank drill, driven by a reversible motor at 250 to 300 rpm, or by standard tube cleaning equipment adapted for use with 5/8-inch outside diameter condenser tubes.

Hydrostatic Tests

A hydrostatic test of 8 to 10 psi should be applied at least once a month, and at all other times when there is an indication that air leakage is a possible cause of an operating difficulty. A hydrostatic test should also be applied after reassembly when the plant has been dismantled for cleaning.

The importance of finding and eliminating air leaks cannot be overemphasized—even small leaks can upset distilling plant operation. It is especially important to eliminate every trace of leakage in vacuum pump suction lines and in the vent and gage lines connected to them. Small leaks, in vacuum return lines to main condensers where first-effect tube nest drain pumps are not employed, can easily cause improper drainage to the first-effect tube nest.

A low pressure hydrostatic test can be made on a distilling plant without removal of any of the units. This test can be made quickly by means of the circulating water pump. For a complete description of this test, check the manufacturer's instruction manual for the distilling plant equipment aboard your ship.

Miscellaneous Cleaning

When the distilling plant is dismantled for cleaning evaporator tubes, a number of other parts should be inspected, and cleaned if necessary. The feed water distributing pipes, flushing pipes, and separate drain lines should be removed and any scale deposits cleaned out. The hooks and troughs on the baffles should be cleaned to

ensure proper drainage. The upper and lower gage glass equalizer lines, gage glass fittings, gage and sight glasses, feed lines between effects, brine lines, and brine pump impeller should all be inspected, and cleaned if necessary.

Inspection of Zincs

Zinc rods or plates are usually provided in all the salt water units of a plant (except the evaporator shell) to reduce the effects of galvanic action on structural parts. The zinc should be inspected and cleaned once a month. When a zinc is more than half corroded, a new one should be installed.

A new type of high-purity zinc, known as ANODE ZINC, is being installed on naval ships. Zinc protectors made of this material have the ability to slough off corrosion products as rapidly as they are formed. This characteristic allows the zinc to give continuous protection against galvanic action, since the zinc does not become encrusted with corrosion products.

Follow Manufacturer's Instructions

It is the responsibility of every distilling plant operator to follow the manufacturer's operating instructions, and to observe the precautionary and maintenance measures mentioned throughout this chapter. This will ensure that the plant output will be maintained at its designed rate.

OPERATION IN CONTAMINATED WATERS

When operating in contaminated waters (water containing dangerous or disease-bearing bacteria), additional precautions must be taken to ensure that the specified standards of chloride concentrations are maintained. Unless, under such conditions, the instructions listed below are rigidly followed to ensure that the distillate is pure enough for drinking, cooking, and bathing, the health of the ship's crew may be endangered.

1. The plant must be operated at a low distilling rate, with comparatively low water levels in each evaporator shell to minimize the possibility of priming or carrying over water particles with the vapor.
2. It is forbidden to transfer evaporator distilled water to the ship's drinking tank if the chloride content exceeds 0.065 epm. If the method of operation does not ensure that no momentary flow may be above 0.065 epm, the temperature of the first-effect shell must be maintained at not less than 165° F.
3. When operating in fresh or brackish contaminated water, the temperature of the first-effect shell must be maintained at not less than 165° F at all times. In such water, a low chloride content will indicate neither freedom from priming and carry over, nor that the distillate is free from harmful contamination. In addition to maintaining this temperature, a low water level should also be maintained in the evaporator shell, to help prevent particles of feed water from mixing with the water vapor.

In many areas, such as harbors, the presence of large amounts of vegetable matter and fuel oil (or both) may cause difficulties in the operation of distilling plants by coating the tube surfaces of the evaporators and heat exchangers with an organic deposit which is difficult to remove. Before entering areas where fouling of the evaporators may be expected, all fresh water tanks should be filled to avoid the necessity of using the distilling plants.

In addition to specially designated areas, all water (unless determined otherwise by suitable tests) in harbors, rivers, in'ets, bays, land-locked waters, and the open sea within 10 miles of the entrance to such waters, is considered contaminated.

QUIZ

1. What are the basic units of a distilling plant?
2. What type of distilling plant is ordinarily installed on all steam driven vessels?
3. Of what type are virtually all low-pressure distilling plants (up to and including the 12,000 gpd plant)?
4. Where are the first- and second-effect feed heaters located on the standard 20,000 gpd triple-effect plant?
5. What is a condensate cooler?
6. What unit of a distilling plant removes the noncondensable gases from the condenser?
7. Into what is the distillate from the air ejector condenser discharged?
8. Where is the drain regulator installed?
9. What steam pressure is maintained above the orifice in the steam supply to the first-effect evaporator?
10. From what source is the generative steam generally supplied?
11. What is referred to as vapor?
12. By what means are the particles of feed water removed from the vapor?
13. Where do the air and noncondensable vapors that enter the plant tend to collect?
14. For what steam pressure is an air ejector usually designed?
15. From what does the distilling condenser circulating water pump take its suction?
16. How many passes does the cooling water make through the distilling condenser?
17. What is used as feed water for the first-effect evaporator?
18. Why are the feed valves to the first-effect, and between effects closed when starting a plant?
19. In starting a plant, to what level should the evaporator shells be filled?
20. When a condensate level appears in the drain regulator gage glasses on the second- and third-effect shells, what should you do?

21. What brine concentration should be maintained at the brine overboard discharge?

22. If the chloride content of the distilled water exceeds 0.12 epm, what must be done?

23. Why is it necessary to maintain a constant last-effect shell pressure?

24. How many inches of vacuum must be maintained in the last-effect shell?

25. Why is it necessary to lower the water levels in the evaporator shells when a ship is at sea?

26. What is the concentration of sea water generally assumed to be?

27. What precaution must be observed in connecting and using centrifugal pumps which operate below atmospheric pressure?

28. How often should the distillate be tested chemically for the presence of chloride?

29. What is the purpose of using the cornstarch-boiler compound for treating evaporator feed water?

30. What takes place when steam is admitted into the tubes when chill shocking a plant?

31. In securing a low-pressure plant, after securing the valve in the steam line supplying the first-effect tube nest, and securing the steam supply to the air ejector, what would your next step be?

32. Why are all the valves in the steam chest vent lines opened when securing the plant?

33. What happens when the brine pump suction strainer becomes clogged?

34. What is the effect of clogging or scoring the air ejector nozzle?

35. What is the maximum allowable chloride content for distilled water used for drinking purposes?

CHAPTER 11

REFRIGERATION

As a Machinist's Mate, you should have a knowledge of refrigeration and air conditioning systems. From practical experience, you will probably learn how to start, operate, stand watch on, and secure these systems. To do your job properly, however, you must have a thorough understanding of the operating principles of a refrigeration or air conditioning system; and this understanding can be attained only through study.

The refrigeration system most commonly used in the Navy utilizes Freon-12 as a refrigerant. The information given in this chapter is, therefore, primarily concerned with Freon-12 systems. It should be noted that the cycle of operation and the main components of Freon-12 systems are basically the same for refrigeration plants and for air conditioning plants.

Basic information on refrigeration is given in *Fireman*, NavPers 10520–A. You may find it helpful to review this material before going on to study the information given in this chapter.

HEAT

The purpose of refrigeration is to cool spaces and to maintain these spaces at a low temperature. Remember, however, that you can't cool anything by adding coolness

to it; you have to REMOVE HEAT from it. Refrigeration, therefore, is a process of cooling by removing heat.

Heat and Temperature

It is important to distinguish between heat and temperature. HEAT is a form of energy. TEMPERATURE is a measure of the intensity of heat—NOT a measure of quantity or amount of heat. Heat is measured in terms of a standard unit called a BRITISH THERMAL UNIT (Btu). Temperature, as you know, is measured in degrees which indicate the intensity of the heat in a given substance, but not the number of Btu in the substance. For example, let's consider a spoonful of very hot water and a bucketful of warm water. Which has the higher temperature? Which has more heat? The heat in the spoonful of hot water is more intense; therefore, its temperature is higher. The bucketful of warm water has more Btu (more heat energy), but its heat is less intense.

British Thermal Unit

The British thermal unit (Btu) is defined as the amount of heat that is required to raise the temperature of 1 pound of water from 59° to 60° F at atmospheric pressure. The temperatures are stated in this definition because the amount of heat required to raise the temperature of 1 pound of water 1° Fahrenheit is not constant at all temperatures. For all practical engineering purposes, however, a British thermal unit may be defined as the AMOUNT OF HEAT REQUIRED TO RAISE THE TEMPERATURE OF 1 POUND OF WATER 1° F at atmospheric pressure.

Sensible Heat and Latent Heat

In the study of refrigeration, it is necessary to distinguish between sensible heat and latent heat. SENSIBLE HEAT is the term applied to the heat that is absorbed or given off by a substance that is NOT in the process of changing its physical state. When a substance is not in

process of changing state, the addition or removal of heat always causes a change in the temperature of the substance.

LATENT HEAT is the term used to describe the heat that is absorbed or given off by a substance while it is changing its physical state. When a substance is in process of changing its physical state, the heat absorbed or given off does NOT cause a temperature change in the substance. In other words, sensible heat is the term used to describe heat that affects the temperature of things; latent heat is the term used to describe heat that affects the physical state of things.

Let's consider the matter of change of state a little further, in order to understand the concept of latent heat. Many substances may exist as solids, as liquids, or as gases, depending primarily upon the temperatures and pressures to which they are subjected. If the pressure is kept constant, the physical state of a substance will depend upon its temperature. To change a solid to a liquid, or a liquid to a gas, it is necessary to ADD HEAT (Btu); to change a gas to a liquid, or a liquid to a solid, it is necessary to REMOVE heat (Btu). The heat required to change the physical state of the substance, WITHOUT any change in temperature, is termed LATENT HEAT. You might say that latent heat is the price, in terms of heat energy, that must be paid for a change of state.

Suppose you take a pan of cold water and put it over a burner. The temperature of the water rises and the sensible heat of the water increases. As you continue adding heat to the water in the pan, the temperature of the water will continue to rise until it reaches 212° F. Any addition of heat at this point causes the water to boil, and to change from a liquid state to a gaseous state; but the temperature remains at 212° F. What is happening? The water is now absorbing its latent heat of vaporization, and is changing from a liquid to a vapor. The heat required to change a liquid to a gas (or, on the other hand, the heat which must be removed from a gas in order to

condense it to a liquid) without any change in temperature is known as the LATENT HEAT OF VAPORIZATION.

Now suppose you take another pan of cold water and put it in a place where the temperature is below 32° F. The water will gradually lose heat to its surroundings, and the temperature of the water will drop to 32° F. The temperature will remain at 32° F until all the water has changed to ice. While the water is changing to ice, however, it is still losing heat to its surroundings. The heat which must be removed from a substance in order to change it from a liquid to a solid (or, on the other hand, the heat which must be added to a solid in order to change it to a liquid) without change of temperature is called the LATENT HEAT OF FUSION.

It should be noted that the amount of heat required to cause a change of state (or, on the other hand, the amount of heat given off when a substance changes its state) varies according to the pressure under which the process takes place.

Figure 11–1 shows the relationship between sensible heat and latent heat for one substance, water, at atmospheric pressure. Let's start out with 1 pound of ice at 0° F. To raise the temperature of the ice to 32° F, we need to add only 16 Btu. To change the pound of ice at 32° F to a pound of water at 32° F, we must add 144 Btu (the latent heat of fusion). There will be no change in temperature while the ice is melting. After all the ice is melted, however, the temperature of the water will be raised when additional heat is applied. If we add 180 Btu (1 Btu for each degree of temperature increase between 32° and 212° F), the water will boil. To change the pound of water at 212° F to a pound of steam at 212° F, we must add 970 Btu (the latent heat of vaporization). After all the water is converted to steam at 212° F, the application of additional heat will cause a rise in the temperature of the steam. If we add 42 Btu to the steam which is at 212° F, we can superheat it to 300° F.

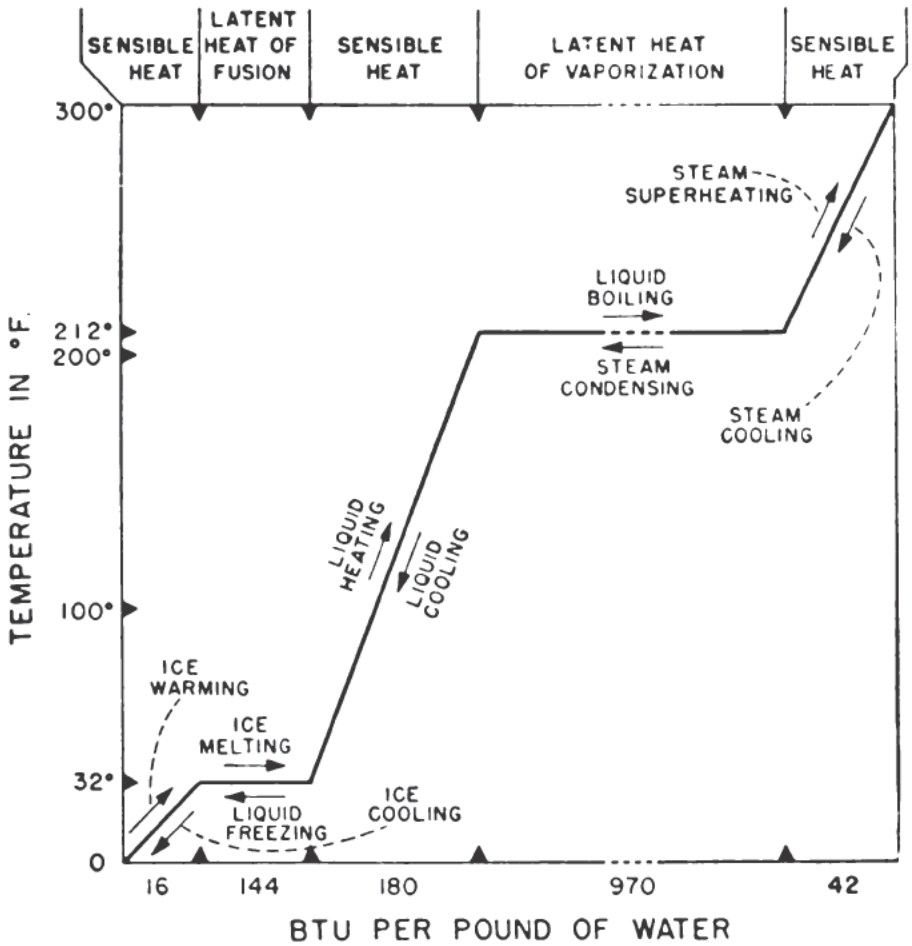


Figure 11-1.—Relationship between sensible heat and latent heat (for water, at atmospheric pressure).

The process we have just described can be reversed, as shown in figure 11–1.

Specific Heat

In the discussion of sensible heat and latent heat, you may have noticed that it takes only 16 Btu to raise the temperature of 1 pound of ice from 0° F to 32° F—that is, only ½ Btu for each degree of rise in temperature. However, you know that it takes 1 Btu to raise the temperature of the same amount of water 1° F. How do you account for this difference?

Substances vary with respect to their ability to absorb heat or to lose heat. The ability of a substance to absorb heat or to lose it is known as the SPECIFIC HEAT of the

substance. The specific heat of water is taken to be 1.0, and the specific heat of each other substance is measured by comparison with this standard. Thus, if it takes only ½ Btu to raise the temperature of 1 pound of a substance 1° F, the specific heat of that substance is 0.5, or one-half the specific heat of water. If you look up the specific heat of ice in a table, you will find it to be about 0.5.

Heat Flow

Heat flows only from objects of higher temperature to objects of lower temperature. When two objects at different temperatures are placed near each other, heat will flow from the warmer object to the cooler one until both objects are at the same temperature. Heat flow takes place at a greater rate when there is a large temperature difference than when there is only a slight temperature difference. As the temperature difference approaches zero, the rate of heat flow also approaches zero. Heat flow may take place by radiation, by conduction, by convection, or by some combination of these methods.

Refrigeration Ton

The unit which measures the amount of heat removal and thereby indicates the capacity of a refrigeration system is known as the REFRIGERATION TON. The refrigeration ton is based on the cooling effect of one ton (2000 pounds) of ice at 32° F melting in 24 hours. As we have seen, the latent heat of fusion of ice (or water) is 144 Btu. Therefore, the number of Btu required to melt one ton of ice is 144×2000, or 288,000. The standard refrigeration ton is defined as the transfer of 288,000 Btu in 24 hours. On an hourly basis, the refrigeration ton is 12,000 Btu per hour (288,000 divided by 24).

It should be emphasized that the refrigeration ton is the standard unit of measure used to designate the heat-removal capacity of a refrigeration unit. It is not necessarily a measure of the amount of ice the unit can make in a given length of time.

PRESSURE, TEMPERATURE, AND VOLUME

In studying refrigeration, it is important to understand some of the ways in which pressure affects liquids and gases, and some of the relationships between pressure, temperature, and volume in gases.

The boiling point of any liquid varies according to the pressure on the liquid—the higher the pressure, the higher the boiling point. It is well to remember that condensing a gas to a liquid is just the reverse process of boiling a liquid until it vaporizes, and that the same pressure and temperature relationship is required to produce either change of state.

Water boils at 80° F under a vacuum of 29 inches of mercury; at 212° F at atmospheric pressure; and at 489° F at a pressure of 600 psig. Refrigerants have much lower boiling points than water, under any given pressure, but these boiling points also vary according to pressure. Freon-12, for example, boils at —21° F at atmospheric pressure; at 0° F at 9.17 psig; at 50° F at 46.69 psig; and at 100° F at 116.9 psig. From these figures, you can see that Freon-12 cannot exist as a liquid at ordinary temperatures unless it is confined and put under pressure.

If the temperature of a liquid is raised to the boiling point corresponding to its pressure, and if the application of heat is continued, the liquid begins to boil and vaporize. The vapor which is formed remains at the same temperature as the boiling liquid, as long as it is in contact with the liquid. A vapor CANNOT be superheated as long as it is in contact with the liquid from which it is being generated.

The pressure-temperature-volume relationships of gases are expressed by Boyle's law, Charles' law, and the general gas law.

BOYLE'S LAW states that the volume of any dry gas varies inversely with its absolute pressure, provided the temperature remains constant. This law may also be expressed as an equation:

$$V_1 P_1 = V_2 P_2$$

where V_1 is the original volume of the gas, P_1 its original absolute pressure, V_2 its new volume, and P_2 its new absolute pressure.

CHARLES' LAW states that the volume of a gas is directly proportional to its absolute temperature, provided the pressure is kept constant. The equation for this law is:

$$V_1 T_2 = V_2 T_1$$

THE GENERAL GAS LAW combines Boyle's law and Charles' law, and expresses the relationship between the volume, the absolute pressure, and the absolute temperature of gases. The general gas law is expressed by the equation:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

These equations indicate the nature of the relationship between the pressure, the volume, and the temperature of any gas. You will probably not find it necessary to use the equations themselves, but you should have a thorough understanding of the principles which they express. Let's summarize them:

1. When temperature is held constant, increasing the pressure on a gas causes a proportional decrease in volume; decreasing the pressure causes a proportional increase in volume.
2. When pressure is held constant, increasing the temperature of a gas causes a proportional increase in volume; decreasing the temperature causes a proportional decrease in volume.
3. When the volume is held constant, increasing the temperature of a gas causes a proportional increase in pressure; decreasing the temperature causes a proportional decrease in pressure.

In this discussion of the effects of pressure on a gas, we have noted that the volume and the temperature of the

gas are different AFTER the pressure has been changed. It is important to note, however, that a temperature change normally occurs in a gas WHILE the pressure is being changed. Compressing a gas raises its temperature; allowing a gas to expand lowers its temperature. As we will see, this fact is of importance in the refrigeration cycle.

MECHANICAL REFRIGERATION SYSTEMS

The two types of mechanical refrigeration systems most commonly used on board ship are (1) the steam-jet type; and (2) the Freon-12 type.

The STEAM-JET REFRIGERATION SYSTEM is used on some naval vessels for air-conditioning purposes, and on some merchant ships for large-area, moderate-temperature refrigeration. As shown in figure 11–2, the steam-jet plant consists of a flash tank, a booster ejector, a condenser, air ejectors, and the necessary pumps and piping. The flash tank (sometimes called the evaporator) is maintained under exceptionally high vacuum by a steam-jet booster ejector. As water is sprayed into the flash tank, part of each drop flashes into vapor and thereby cools the unvaporized portion of each drop to about 50° F or lower, depending upon the capacity of the unit. The cooled water falls to the bottom of the shell; it is then pumped to the cooling coils, and returned to the flash tank at a temperature of about 55° F.

The FREON-12 SYSTEM is used for most naval refrigeration plants. Figure 11–3 gives a general idea of this type of refrigeration cycle. As you study this system, try to understand what happens to the refrigerant as it passes through each part of the cycle. In particular, be sure that you understand why the refrigerant changes from liquid to vapor and from vapor to liquid, and what happens in terms of heat because of these changes of state. It will be helpful to trace the refrigerant through its entire cycle, beginning with the thermostatic expansion valve.

Liquid Freon-12 enters the expansion valve from the

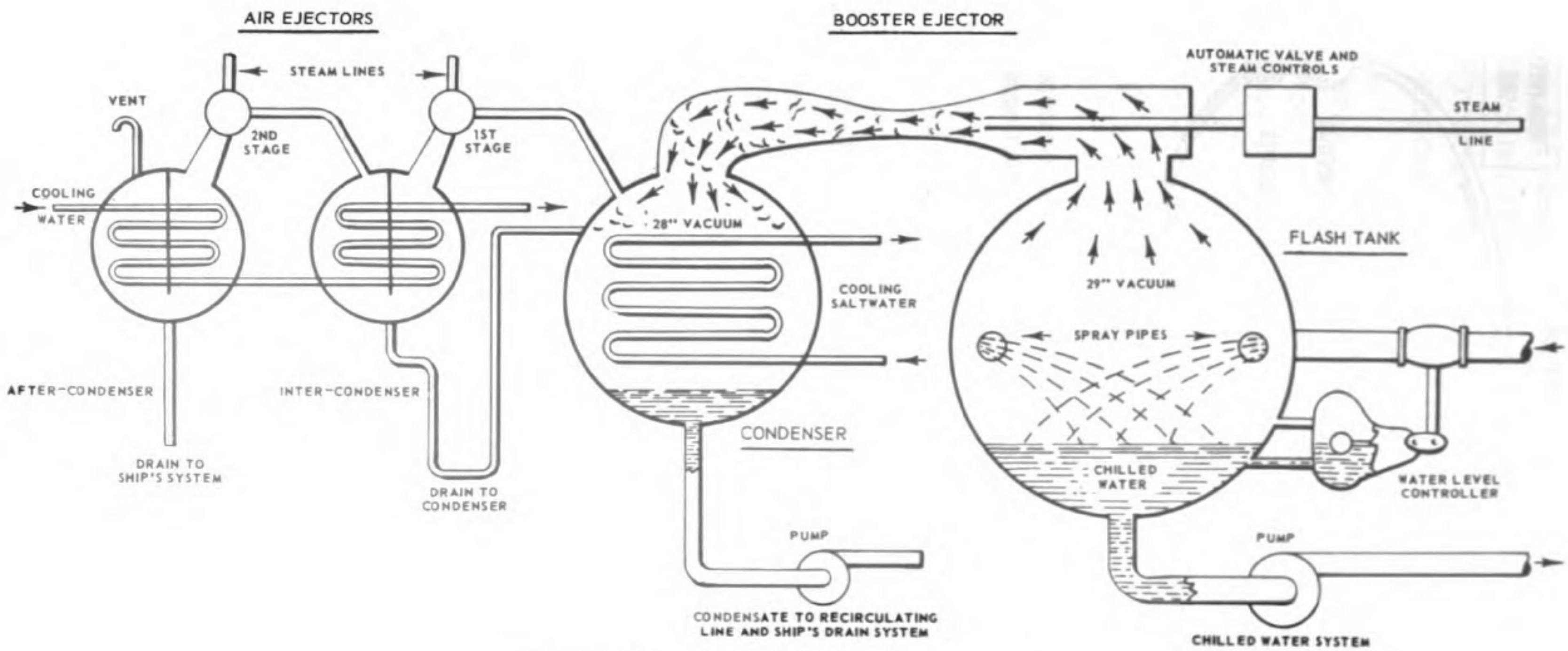


Figure 11-2.—Steam-jet refrigeration system.

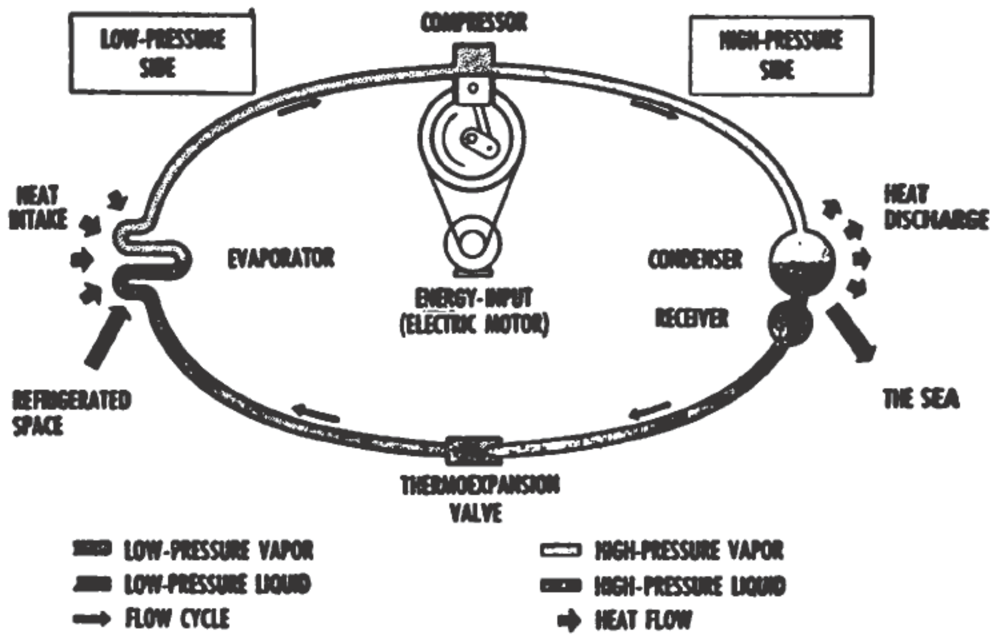


Figure 11-3.—Freon-12 refrigeration cycle.

high-pressure side of the system, at high pressure. The expansion valve acts as a reducing valve; therefore, the Freon-12 leaves the outlet orifice of the valve at a much lower pressure. Due to the reduction in pressure, the liquid refrigerant begins to boil and to flash into vapor.

From the thermostatic expansion valve, the refrigerant passes into the cooling coil (or evaporator). The boiling point of the refrigerant under the low pressure in the evaporator is extremely low—much lower than the temperature of the space in which the cooling coil is installed. As the liquid boils and vaporizes, it picks up its latent heat of vaporization from the surroundings, thereby cooling the space. The refrigerant continues to absorb latent heat of vaporization until all the liquid has been vaporized. By the time the refrigerant is ready to leave the cooling coil, it has not only absorbed this latent heat of vaporization, but has also picked up some additional heat—that is, the vapor has become superheated. As a rule, the amount of superheat is 10° F.

The refrigerant leaves the evaporator as a low-pressure superheated vapor, having absorbed heat and thus cooled

the space to the desired temperature. The remainder of the cycle is concerned with disposing of this heat and getting the refrigerant back into a liquid state so that it can again vaporize in the evaporator and thus again absorb heat.

The low-pressure superheated vapor is drawn out of the evaporator by the suction of the compressor. The compressor, therefore, is the mechanism which keeps the refrigerant circulating through the system. In the compressor cylinders, the refrigerant is compressed from a low-pressure vapor to a high-pressure vapor, and its temperature rises accordingly.

The high-pressure Freon-12 vapor is discharged from the compressor into the condenser. Here the refrigerant condenses, giving up its superheat (sensible heat) and its latent heat of vaporization to the cooling sea water which flows through the condenser tubing. The refrigerant, still at high pressure, is now a liquid again.

From the condenser, the refrigerant flows into a receiver, which serves as a storage place for the liquid refrigerant in the system. From the receiver, the refrigerant goes to the thermostatic expansion valve, and the cycle begins again.

As you can see from this description of the compression cycle, this type of refrigeration system has two pressure sides. The LOW-PRESSURE SIDE extends from the orifice of the thermostatic expansion valve up to and including the intake side of the compressor cylinders. The HIGH-PRESSURE SIDE extends from the discharge valve of the compressor to the thermostatic expansion valve.

MAIN PARTS OF THE FREON-12 SYSTEM

The main parts of a Freon-12 refrigeration system are shown diagrammatically in figure 11–4. The primary components of the system are the thermostatic expansion valve, the evaporator, the compressor, the condenser, and the receiver. Additional equipment required to complete the plant includes piping, pressure gages, thermometers,

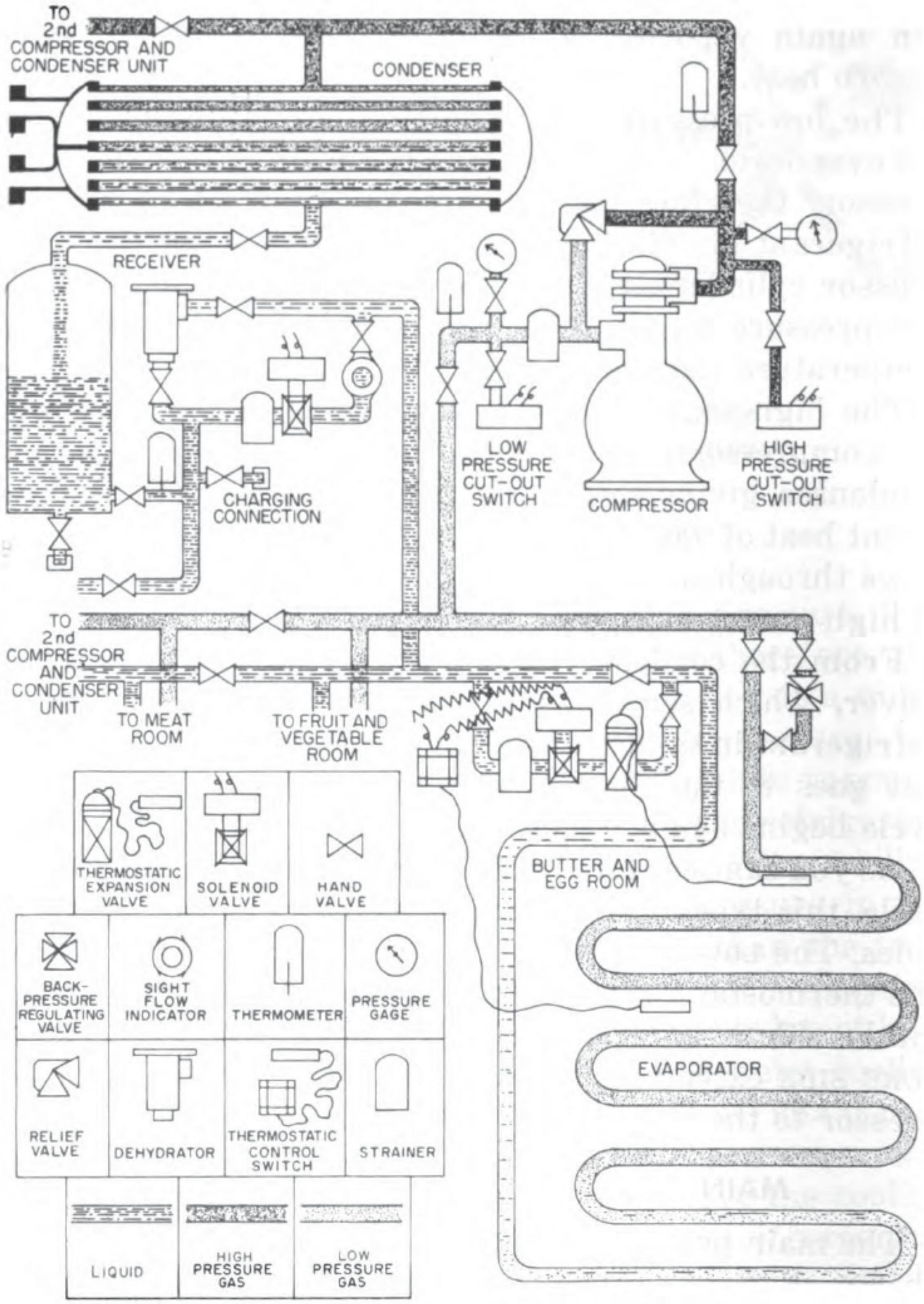


Figure 11-4.—Diagram of Freon-12 refrigeration system.

various types of control switches and control valves, strainers, relief valves, sight flow indicators, dehydrators, charging connections, etc. Figure 11–5 shows most of the components on the high-pressure side of a Freon-12 system, as actually installed on board ship.

In the following discussion, we will deal with the Freon-12 system as though it had only one evaporator, one compressor, and one condenser. As you will see from figure 11–4, however, a refrigeration system may (and, indeed, usually does) include more than one evaporator; and it may include additional compressor and condenser units.

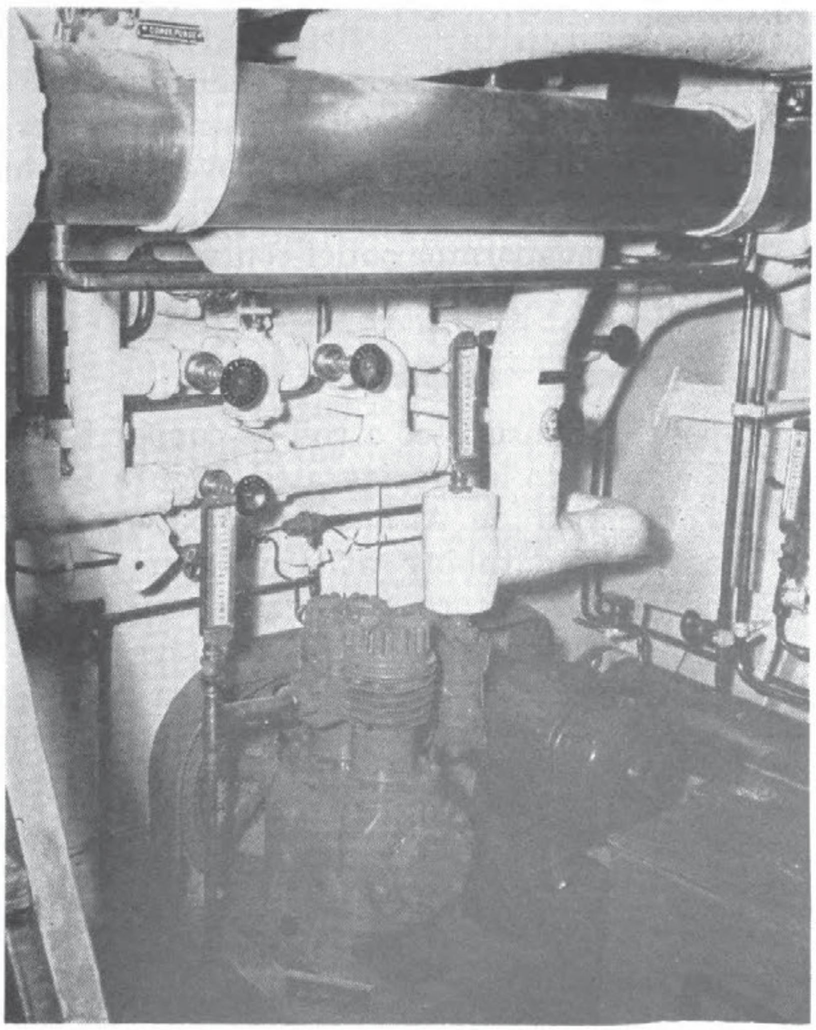


Figure 11–5.—Freon-12 installation.

Thermostatic Expansion Valve

The thermostatic expansion valve is essentially a reducing valve between the high-pressure side and the low-pressure side of the system. The valve is designed to feed just the right amount of refrigerant into the cooling coil; the amount depends, of course, on the amount of heat being removed from the refrigerated space.

A thermal control bulb for the thermostatic expansion valve is clamped to the cooling coil, near the outlet. The bulb contains Freon-12. Control tubing connects the bulb with the area above the diaphragm in the thermostatic expansion valve. When the temperature at the control bulb rises, the Freon expands and transmits a pressure to the diaphragm; this causes the diaphragm to be moved downward, thus opening the valve and allowing more refrigerant to enter the cooling coil. When the temperature at the control bulb falls, the pressure above the diaphragm is decreased and the valve tends to close. Thus, the temperature near the evaporator outlet controls the operation of the thermostatic expansion valve.

Evaporator

The evaporator consists of a coil of copper tubing installed in the space to be refrigerated. Figure 11–6 illustrates some of this tubing. As mentioned before, the liquid Freon-12 enters the tubing at a very much reduced pressure and with, therefore, a very much lowered boiling point. In passing through the expansion valve, going from the high-pressure side of the system to the low-pressure side, a certain amount of heat must be removed from the refrigerant in order to reduce its temperature to the boiling point at the pressure in the evaporator. As part of the refrigerant boils and vaporizes, due to the reduced pressure, the remaining liquid refrigerant is cooled to its boiling point. Then, as the refrigerant passes through the evaporator, the heat flowing to the coil from the surrounding air causes the rest of the liquid refrigerant to boil

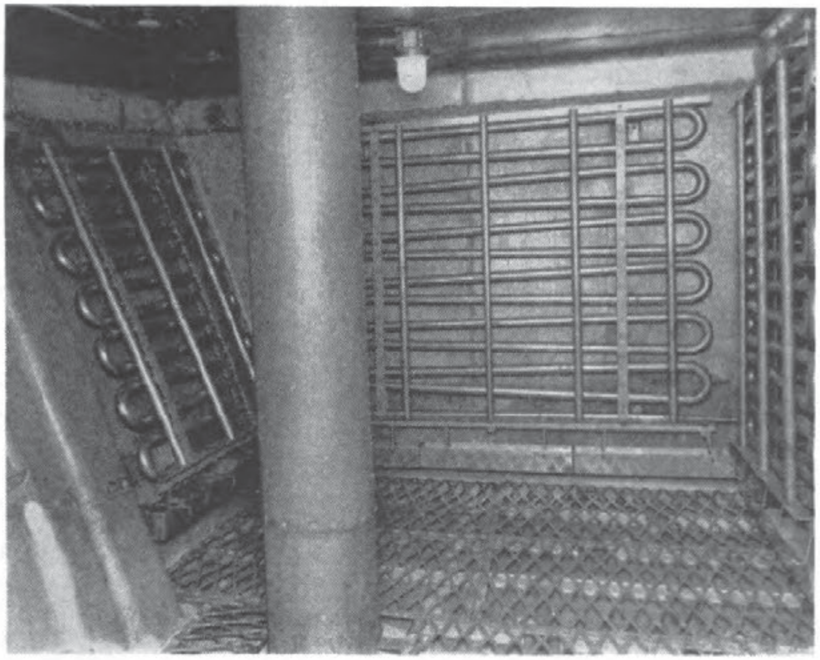


Figure 11-6.—Evaporator tubing.

and vaporize. After the refrigerant has absorbed its latent heat of vaporization (that is, after it is entirely vaporized), the refrigerant continues to absorb heat until it becomes superheated by about 10° F. The amount of superheat is determined by the amount of liquid refrigerant admitted to the evaporator; and this, in turn, is controlled by the spring adjustment of the thermostatic expansion valve. About 10° F of superheat is considered desirable because it increases the efficiency of the plant and because it dries the vapor, preventing liquid carry-over into the compressor.

Compressor

The compressor in a refrigeration system is essentially a pump. It is used to pump heat "uphill" from the cold side to the hot side of the system.

The heat absorbed by the refrigerant in the evaporator must be removed before the refrigerant can again absorb latent heat. The only way in which the vaporized refrigerant can be made to give up the latent heat of

vaporization that it absorbed in the evaporator is by cooling and condensing it. In view of the relatively high temperature of the available cooling medium, the only way to make the vapor condense is by first compressing it.

The vapor drawn into the compressor is at very low pressure and very low temperature. In the compressor, both the pressure and the temperature are raised. Since an increase in pressure causes a proportional rise in temperature, and since the condensation point of any vapor is dependent upon the pressure, raising the pressure of the vaporized refrigerant provides a condensation temperature high enough to permit the use of sea water as the condensing and cooling medium. The compressor raises the pressure of the vaporized refrigerant sufficiently high to permit heat transfer and condensation to take place in the condenser.

In addition to this primary function, the compressor also serves to keep the refrigerant circulating and to maintain the required pressure difference between the high-pressure side and the low-pressure side of the system.

Many different types of compressors are used in refrigeration systems. Figure 11–7 shows a motor-driven, single-acting, two-cylinder, reciprocating compressor such as is commonly used in naval refrigeration plants.

Compressors used in Freon-12 systems may be lubricated either by pressure lubrication or by splash lubrication. Splash lubrication, which depends upon maintaining a fairly high oil level in the compressor crankcase, is usually satisfactory for smaller compressors.

Condenser

The compressor discharges the high-pressure, high-temperature refrigerant vapor to the condenser, where it flows around the tubes through which sea water is being pumped. As the vapor gives up its superheat (sensible heat) to the sea water, the temperature of the vapor drops to the condensation point. As soon as the temperature of

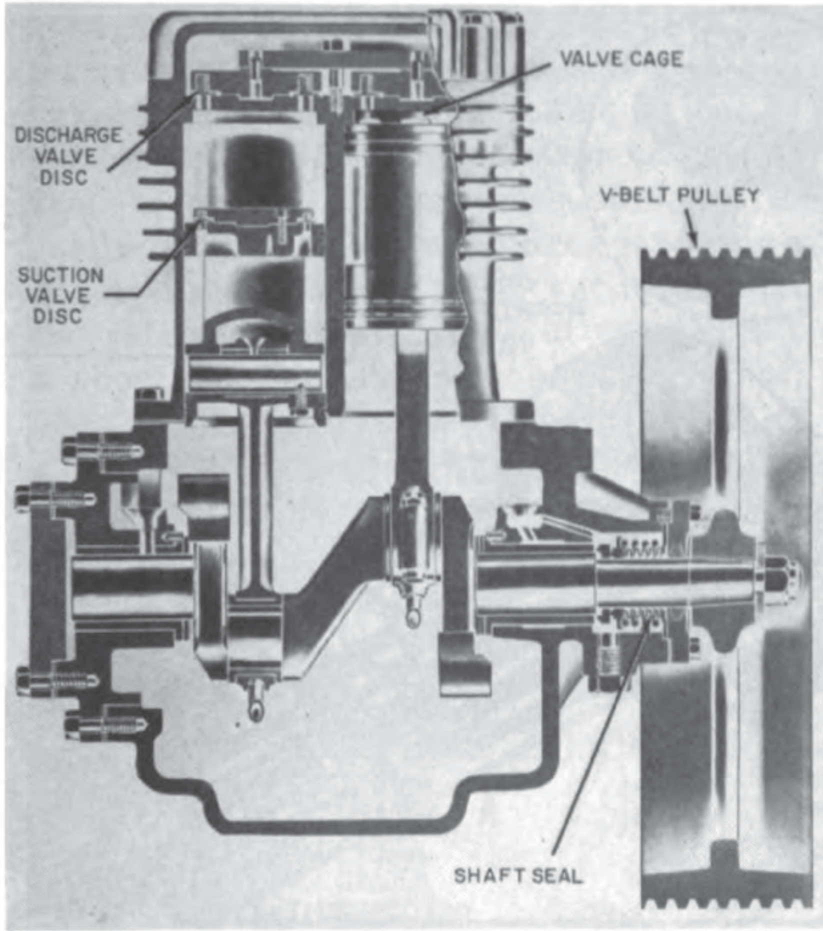


Figure 11–7.—Reciprocating compressor.

the vapor drops to its boiling or condensing temperature at the existing pressure, the vapor condenses, giving off its latent heat of vaporization in the process. The refrigerant, now in liquid form, is subcooled slightly below its boiling point (condensation point) at this pressure to ensure that it will not flash into vapor. The extent to which the liquid refrigerant is subcooled in the condenser depends upon the rate of flow of the sea water through the condenser tubes.

A water-cooled condenser for a Freon-12 refrigeration system is shown in figure 11–8. Circulating water is obtained through a branch connection from the firemain, or by means of an individual pump taking suction from the sea. The purge connection shown in figure 11–8 is on

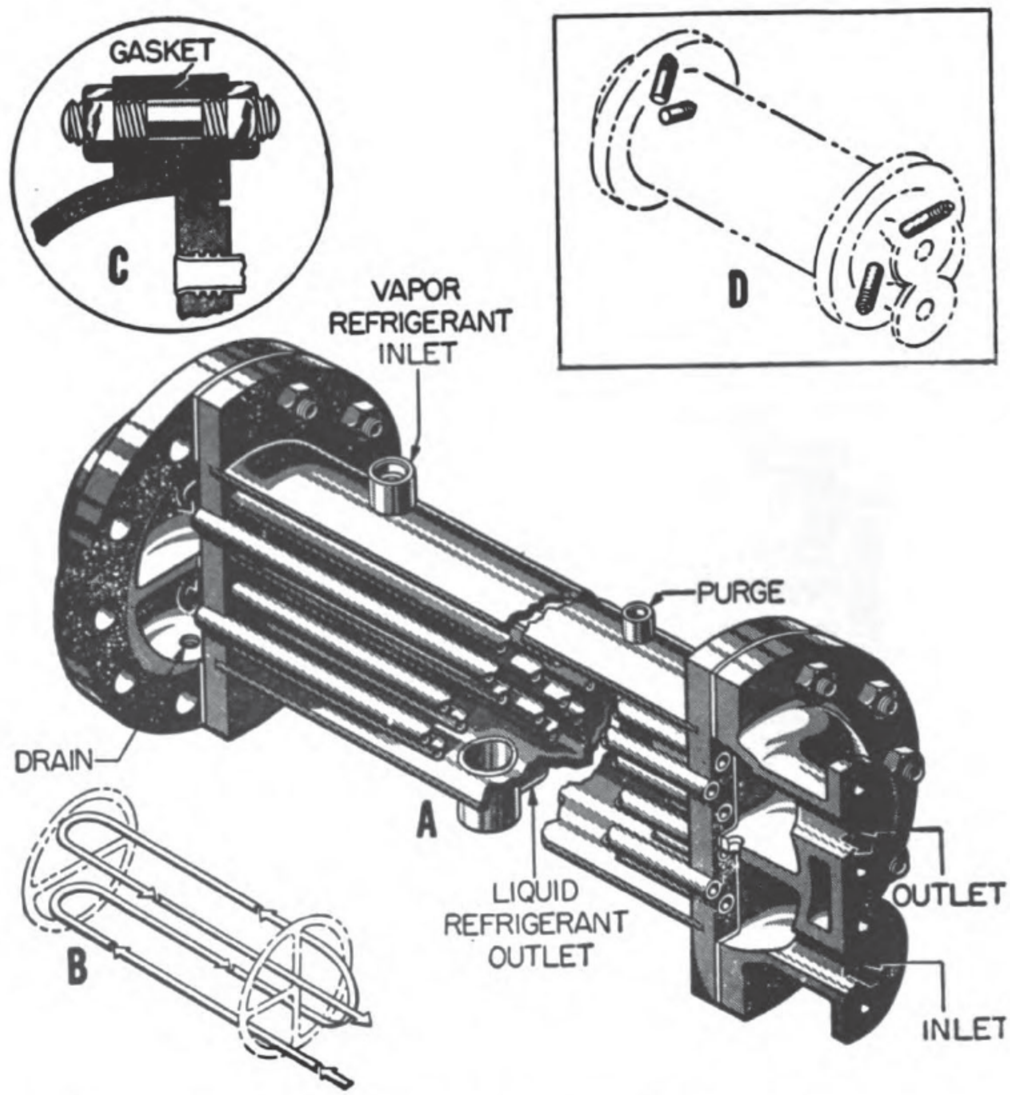


Figure 11–8.—Water-cooled condenser for Freon-12 refrigeration system. (A) Cutaway view; (B) water-flow diagram; (C) arrangement of head joint; and (D) position of zincs.

the refrigerant side; it is used to remove air and other unwanted gases that are lighter than the Freon vapor.

Most condensers used for naval refrigeration plants are of the water-cooled type. However, it should be mentioned that some small units have air-cooled condensers. These consist of tubing with external fins to increase the heat-transfer surface. Most air-cooled condensers have fans to ensure positive circulation of air around the condenser.

Receiver

The receiver, shown in figure 11–9, acts as a temporary storage space and surge tank for the liquid Freon which flows from the condenser. The receiver also serves as a vapor seal, to prevent the entrance of vapor into the liquid line to the expansion valve. Receivers may be constructed for either horizontal or vertical installation. When the refrigeration system is in operation, the receiver is about one-third full of liquid refrigerant.

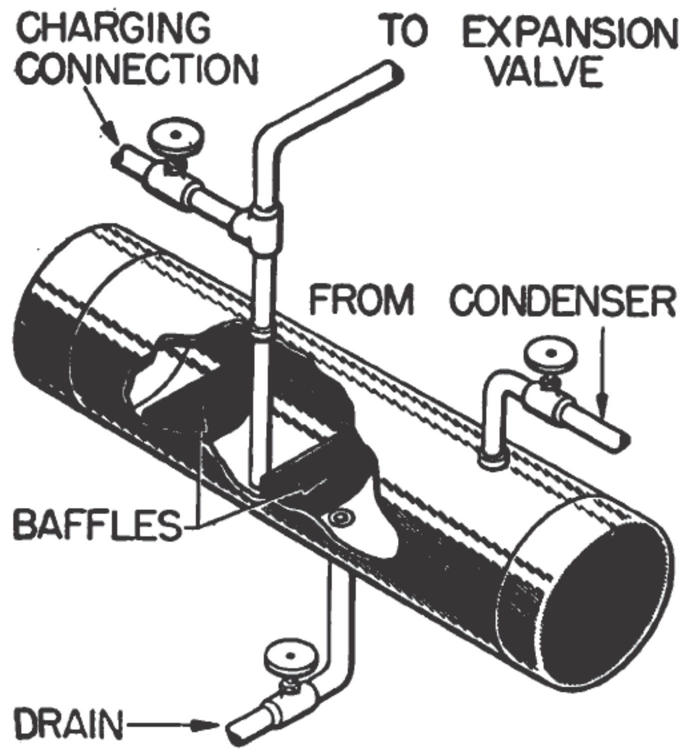


Figure 11–9.—Receiver.

Accessories

In addition to the five main components just described, a refrigeration system requires a number of controls and accessories. The most important of these will be described briefly.

DEHYDRATOR.—A dehydrator, or drier, is placed in the liquid Freon line between the receiver and the thermostatic expansion valve. The dehydrator is used only when

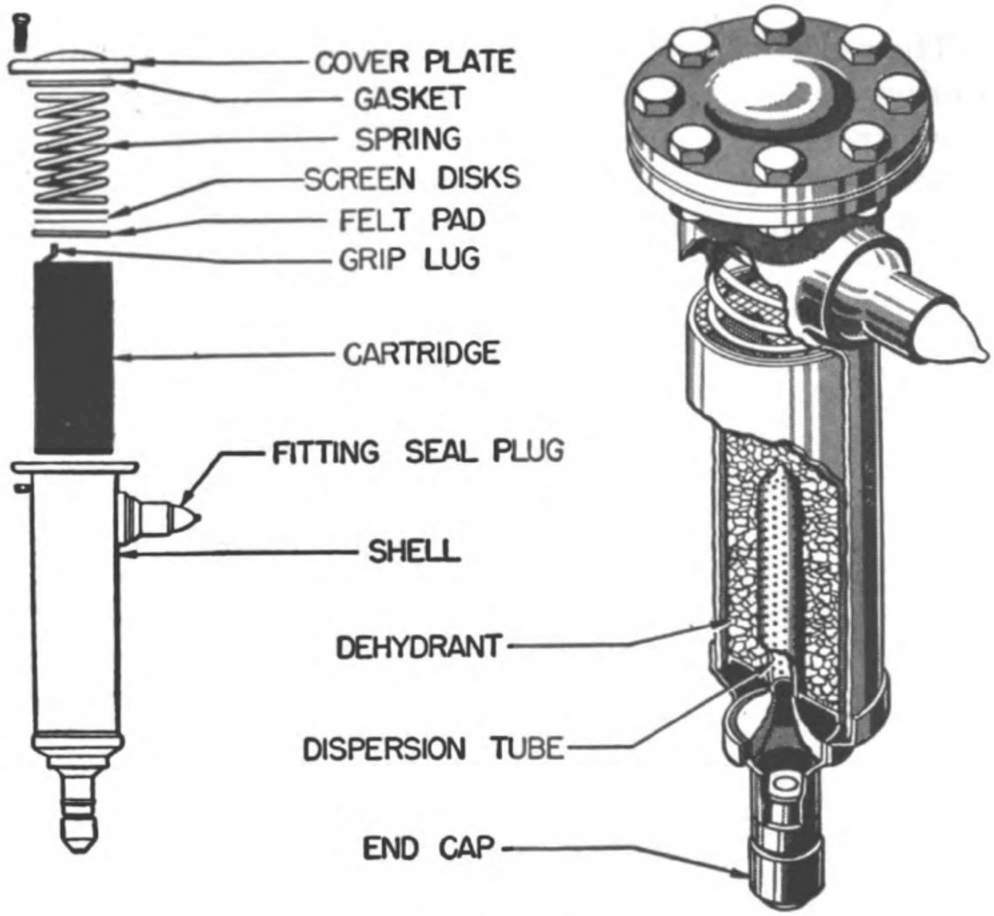


Figure 11–10.—Freon-12 dehydrator.

the system is being charged with Freon-12, or when the presence of moisture is suspected. Bypass valves allow the dehydrator to be cut in or out of the system. The drying agent used in the dehydrator is usually either activated alumina or silica gel. A dehydrator is shown in figure 11–10.

SOLENOID VALVES.—A solenoid valve is installed in the liquid line leading to each evaporator. Figure 11–11 shows a solenoid valve and the thermostatic control switch that operates it. The thermostatic control switch is connected by long flexible tubing to a thermal control bulb which is located in the refrigerated space. When the temperature in the refrigerated space drops to the desired point, the thermal control bulb causes the thermostatic control switch to open, thereby closing the solenoid valve and

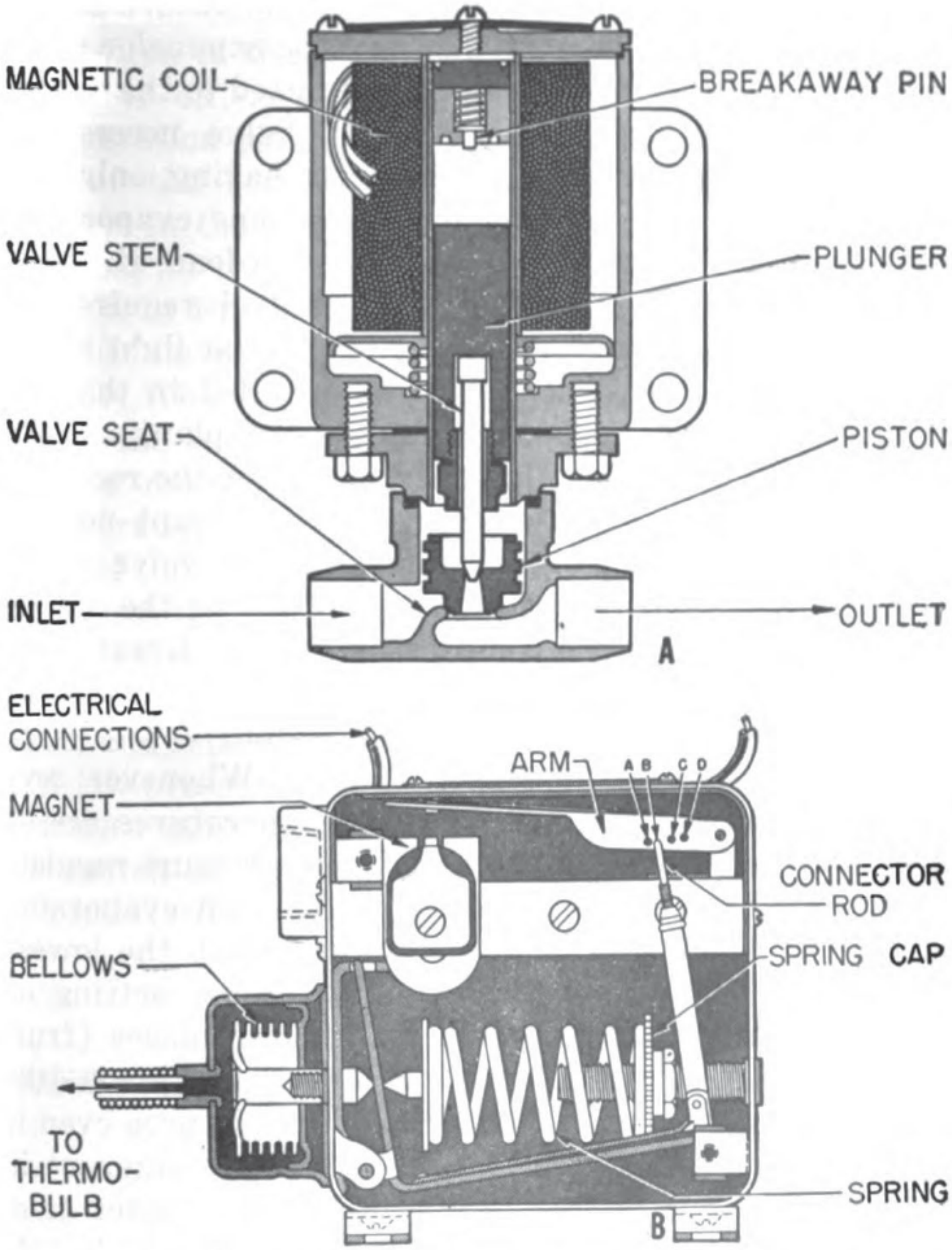


Figure 11–11.—(A) Solenoid valve. (B) Thermostatic control switch.

shutting off all flow of liquid refrigerant to the thermostatic expansion valve. When the temperature in the refrigerated space rises above the desired point, the thermostatic control switch closes, the solenoid valve opens, and liquid refrigerant once again flows to the thermostatic expansion valve.

The solenoid valve and its related thermostatic control

switch serve to maintain the proper temperature in the refrigerated space. Since the thermostatic expansion valve controls the amount of refrigerant admitted to the evaporator, however, why is the solenoid valve necessary? Actually, it is not necessary on units having only one evaporator. On units having more than one evaporator, however, where there is wide variation in load, the solenoid valve provides the additional control required to prevent the spaces from becoming too cold at light loads.

In addition to the solenoid valve installed in the line to each evaporator, a large refrigeration plant usually has a KING solenoid valve installed just after the receiver. If the compressor stops for any reason except normal suction pressure control, the king solenoid valve closes and prevents liquid refrigerant from flooding the evaporator and flowing to the compressor suction. Great damage to the compressor can result if liquid is allowed to enter the compressor suction.

BACK-PRESSURE REGULATING VALVES.—Whenever several refrigerated spaces of varying temperatures are to be maintained by one compressor, a back-pressure regulating valve is installed near the outlet of each evaporator EXCEPT the evaporator in the space in which the lowest temperature is to be maintained. By proper setting of the thermostatic control switches, the other spaces (fruit and vegetable room, butter and egg room, etc.) could be maintained at appropriately higher temperatures even if the same pressure was maintained on the refrigerant in all evaporators. However, maintaining the higher temperature by this method would result in excessively cold coils and excessive frosting of the coils; this, in turn, would cause lowered humidity in the space and dehydration of the refrigerated material. The back-pressure regulating valve is set to keep the pressure in the coil from falling below the pressure corresponding to the temperature at which the coil will remain frost-free and yet cold enough to produce the desired temperature in the space.

LOW-PRESSURE CUTOUT SWITCH.—The low-pressure cutout switch is the control that causes the compressor to go on or off, as required for normal operation of the refrigeration plant. This switch is located on the suction side of the compressor, and is actuated by pressure changes in the suction line. When the solenoid valves in the lines to the various evaporators are closed, so that the flow of Freon to the evaporators is stopped, the pressure of the vapor in the compressor suction line drops quickly. When the suction pressure has dropped to about 2 psi, the low-pressure cutout switch causes the compressor motor to stop. When the temperature in the refrigerated spaces has risen enough to operate one or more of the solenoid valves, refrigerant is again admitted to the cooling coils, and the compressor suction pressure builds up again. At a pressure of about 20 psi, the low-pressure cutout switch closes, starting the compressor again and repeating the cycle.

A low-pressure cutout switch is shown in figure 11–12.

HIGH-PRESSURE CUTOUT SWITCH.—A high-pressure cutout switch is connected to the compressor discharge line to protect the high-pressure side of the system against

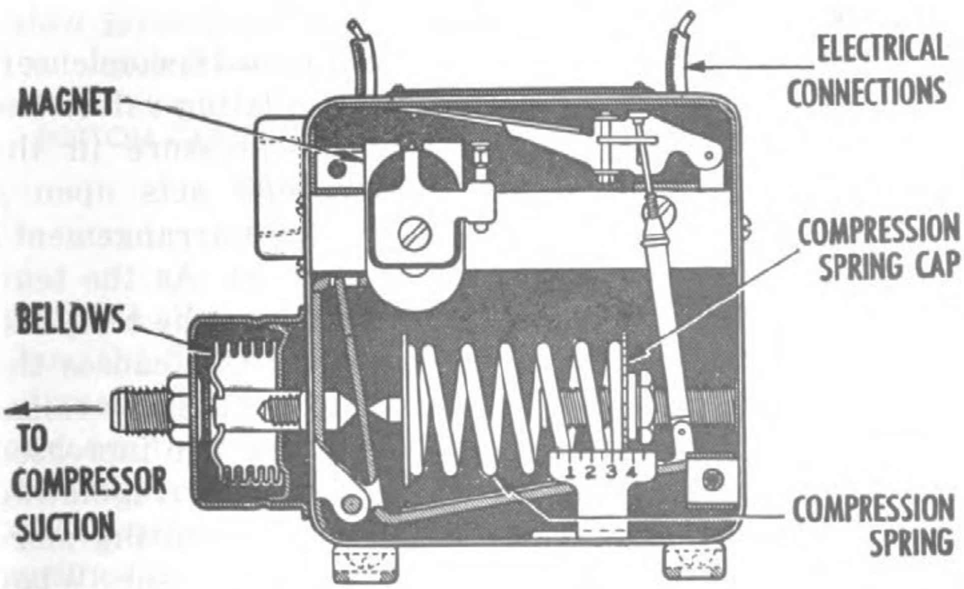


Figure 11–12.—Low-pressure cutout switch.

excessive pressures. The design of this switch is essentially the same as that of the low-pressure cutout switch shown in figure 11–12; however, the low-pressure cutout switch is made to CLOSE when the suction pressure reaches its upper normal limit, whereas the high-pressure cutout switch is made to OPEN when the discharge pressure is too high. The high-pressure switch is normally set to stop the compressor when the pressure reaches about 150 psi, and to start it again when the pressure returns to normal (about 125 psi). As mentioned before, the low-pressure cutout switch is the compressor control for normal operation of the plant; the high-pressure cutout switch, on the other hand, is a safety device only and does not have control of compressor operation under normal conditions.

RELIEF VALVE.—A spring-loaded relief valve is installed in the compressor discharge line as an additional precaution against excessive pressures. The relief valve is set to open at about 225 psi; therefore, it functions only in case of failure or improper setting of the high-pressure cutout switch. If the relief valve opens, it discharges high-pressure vapor to the suction side of the compressor.

WATER REGULATING VALVE.—A water regulating valve is installed to control the quantity of circulating water flowing from the firemain to the Freon-12 condenser. Figure 11–13 shows a typical water regulating valve. The valve is actuated by the refrigerant pressure in the compressor discharge line; this pressure acts upon a diaphragm (or, in some valves, a bellows arrangement) which transmits motion to the valve stem. As the temperature of the circulating water increases, the temperature of the refrigerant vapor increases; this causes the pressure of the refrigerant to increase, and thereby raises the condensation point. When this occurs, the increased pressure of the refrigerant causes the water regulating valve to open wider, thus automatically permitting more circulating water to flow through the condenser. When the condenser is cooler than necessary, the water regulat-

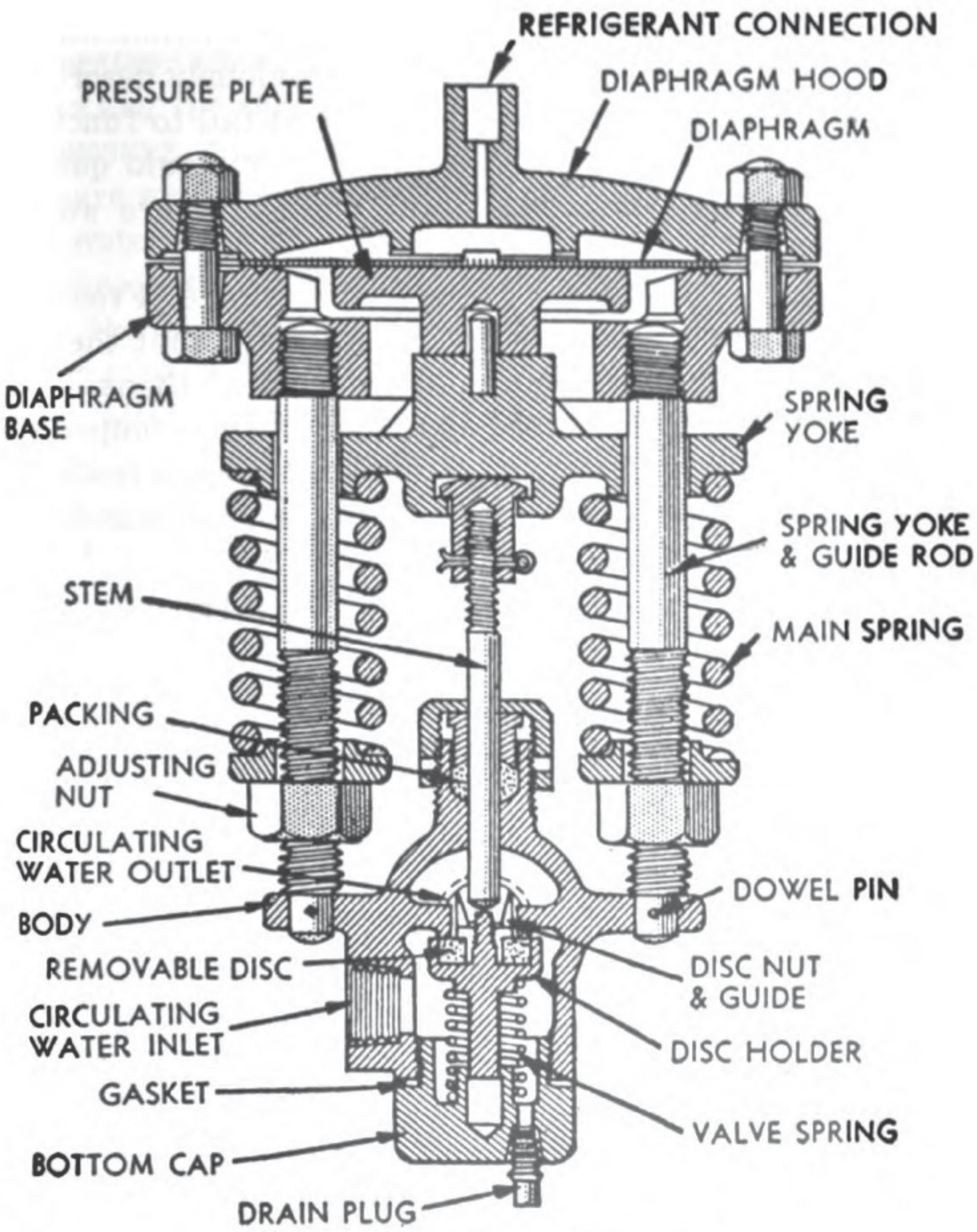


Figure 11–13.—Water regulating valve.

ing valve allows less water to flow through the condenser. Thus, the flow of cooling water through the condenser is automatically maintained at the rate actually required to condense the refrigerant under varying conditions of load and temperature.

WATER-FAILURE CUTOUT SWITCH.—A cutout switch is provided to stop the compressor in the event of failure of the circulating water supply. This is a pressure-actuated

switch, generally similar to the low-pressure cutout switch and the high-pressure cutout switch previously described. If the water-failure cutout switch should fail to function, the refrigerant pressure in the condenser would quickly build up to the point where the high-pressure switch would function.

STRAINERS.—Because of the solvent action of Freon-12, any particles of grit, scale, dirt, metal, etc., that the system may contain are very readily circulated through the refrigerant lines. To avoid damage to the compressor from such foreign matter, a suction scale trap is installed. In addition, a liquid strainer of the type shown in figure

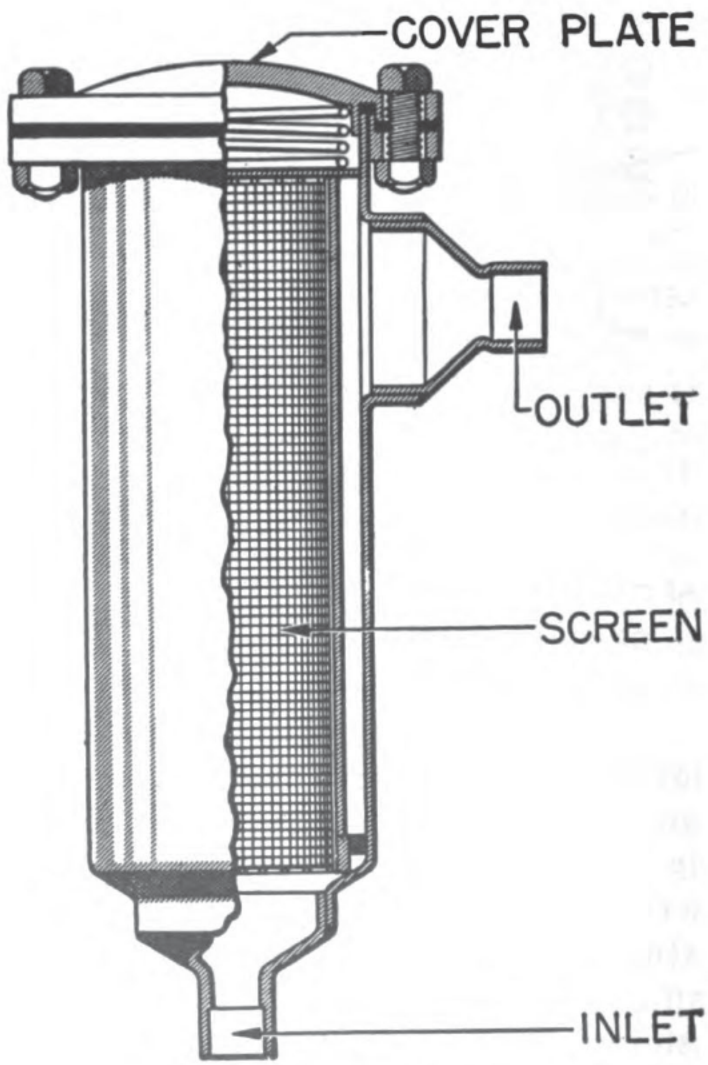


Figure 11–14.—Strainer for liquid refrigerant.

11–14 is installed in the liquid line leading to each evaporator; these strainers serve to protect the solenoid valves and the thermostatic expansion valves.

PRESSURE GAGES AND THERMOMETERS.—A number of pressure gages and thermometers are used in refrigeration systems. Figure 11–15 shows a compound Freon-12 pressure gage. The temperature markings on this gage show the boiling point (or condensation point) of the refrigerant at each pressure; the gage cannot measure temperature directly.

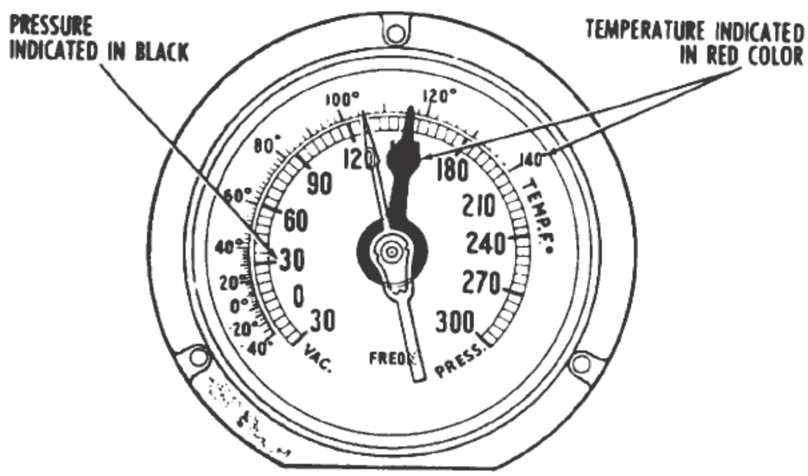


Figure 11–15.—Compound Freon-12 pressure gage.

A water pressure gage is installed in the circulating water line to the condenser, to give visual indication of failure of the circulating water supply.

Standard thermometers of appropriate range are provided for Freon-12 service.

REFRIGERANT PIPING.—Refrigerant piping in modern naval installations is made of copper. Copper is good for this purpose because (1) it does not become corroded by Freon-12; (2) the internal surface of the tubing is smooth enough to minimize friction; and (3) copper tubing is easily shaped to meet installation requirements.

PACKLESS STOP VALVES.—Nearly all hand-operated valves in large refrigeration systems are packless valves

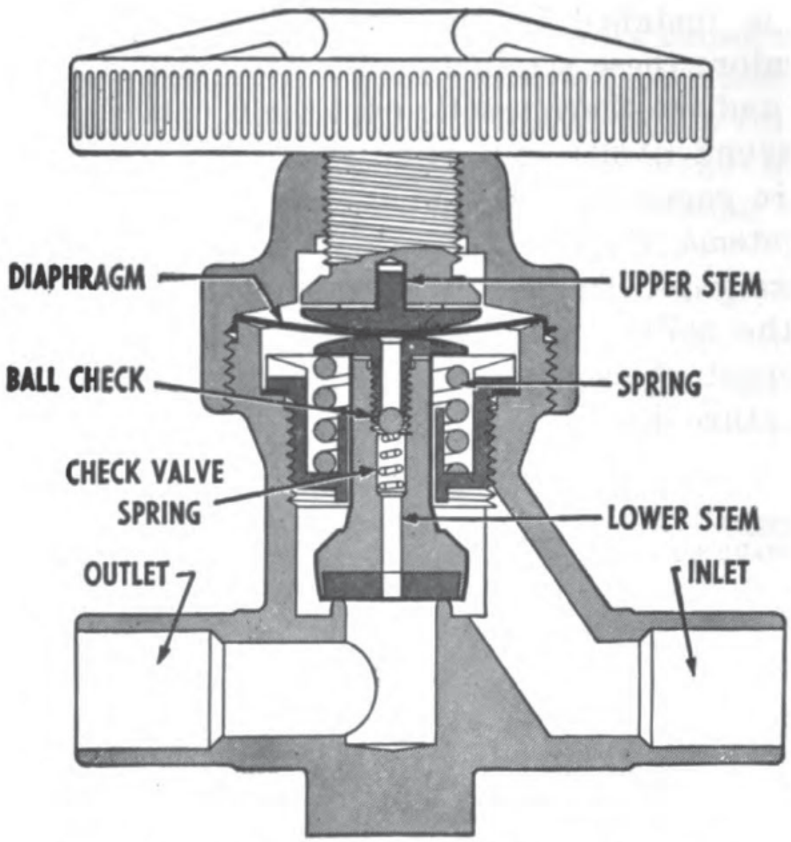


Figure 11–16.—Packless valve for refrigeration system.

of the type shown in figure 11–16. In this type of valve, the upper part of the valve is sealed off from the lower part by a diaphragm. An upward-seating ball check in the lower valve stem makes it possible for the spring to lift the lower stem regardless of pressure differences developed while the valve was closed. Thus, the valve will operate properly regardless of direction of flow.

SUBCOOLERS.—In refrigeration systems where the condenser and the receiver are located a considerable distance below the thermostatic expansion valve, there may be a considerable loss of pressure between the receiver and the thermostatic expansion valve. In such systems, it is necessary to reduce the temperature of the liquid Freon in this part of the system so that the pressure loss will not result in vaporization of the refrigerant before it reaches the expansion valve.

STANDING WATCH ON THE PLANT

Learning how to do all of the tasks related to refrigeration system operation will require a good deal of practical experience and attentive observation of the procedures followed by those qualified in refrigeration system operation and maintenance. As a Third Class Machinist's Mate, your initial responsibility will probably include checking temperatures and pressures, maintaining the plant operating log, detecting symptoms of faulty operation, and checking conditions in the spaces or units being cooled.

When standing a refrigeration or air conditioning watch, you should always notify your leading petty officer or the division duty chief when adjustments are necessary or when abnormal operating conditions exist. Do not attempt to take corrective action by yourself or to make adjustments to a refrigeration plant until you are qualified to do so.

Periodic Checks

The interval of time between plant inspections will vary depending upon the purpose for which the plant is used. The temperatures and pressures throughout the system and the oil level in the compressor crankcase are checked and the results recorded each hour unless watch-standing instructions specify otherwise. The results of these checks can be used to determine whether or not the plant is operating properly. One of the best methods for checking plant operation is to compare the existing temperatures and pressures with those recorded during a period when the plant was known to be operating properly, under conditions similar to the present conditions.

A sight glass is provided in the side of the compressor crankcase for checking the level of the lubricating oil. To check the oil level while the plant is in operation, wait until the compressor shuts down. It is not possible to check the oil level while the compressor is running, since the motion of the parts within the crankcase churns the oil and causes foam.

As soon as the compressor stops, set the automatic-manual selector switch to MANUAL, so that the compressor will not start while you are checking the oil level. Turn the flywheel of the compressor through one revolution and observe the rise and fall of the oil in the sight glass. Record the AVERAGE oil level—that is, the midpoint between the highest and the lowest levels—as the observed oil level. Unless otherwise specified, an oil level between one-fourth and three-fourths on the sight glass is satisfactory. If the oil level is not within the specified range, oil will have to be added or removed. Do not attempt to do this unless you have qualified in the procedures to be followed and are thoroughly familiar with the applicable safety precautions.

Symptoms of Faulty Operation

You must learn to recognize the symptoms of improper plant operation so that you can detect abnormal conditions and correct them before they become acute. Some of the trouble signs that you must learn to recognize are: abnormal pressures in compressor suction or discharge, or in lubricating oil or circulating water supply; abnormal temperatures in the liquid line, at the compressor suction or discharge, in the refrigerated spaces, or at the circulating water overboard discharge; and unusual noises caused by vibration, hydraulic knocks, worn parts in the compressor, or water valve chatter.

Operating Log

The operating record of a refrigeration system must be maintained by the men on watch. The information recorded in the operating log serves as a guide to the condition of the plant. Figure 11–17 shows one page of a typical daily operating log for a refrigeration system.

In addition to the type of information shown in this illustration, the daily operating record should include information on the time each refrigerant compressor and each circulating water pump is started, stopped, and

COMPRESSOR NO. 2

DATE 2 Feb 1953

TIME	MACH. ROOM TEMP.	COMPR. SPEED R.P.M. OR %	COMPRESSOR: F-12 SUCTION LBS. GAGE	F-12 SUCTION TEMP. °F	F-12 DISCHARGE LBS. GAGE	F-12 DISCHARGE TEMP. °F	OIL LBS. GAGE	OIL BULLSEYE LEVEL	CRANKCASE RELATIVE TEMP.	CRANKCASE NOISE	CONDENSER: WATER SUPPLY LBS. GAGE	WATER SUPPLY TEMP. °F	WATER O'B'D. TEMP. °F	F-12 LIQUID: TEMP °F	CONDITION AT SIGHT FLOW	WEATHER: DRY B. TEMP. °F	WET B. TEMP. °F	REFRIGERATED SPACES: ICE SET TEMP. °F	COMPARTMENT TEMPERATURE °F: Meat RM #1	Thaw RM	Veg. RM	Dairy RM	RM	RM
0100	88	540	7	38	95	162	27	OK	warm	OK	24	60	80	82	OK	82	73	7	17	40	34	32		
0200	89	540	4	46	95	162	25	OK	warm	OK	24	60	82	82	OK	82	73	9	15	38	40	32		
0300	89	540	2	56	95	154	22	OK	warm	OK	24	58	80	86	vapor bubbles	80	72	11	19	42	42	36		
0400	88.	540	3	-4	85	143	24	low	cold	knocks	24	58	80	76	OK	80	70	10	14	40	40	34		
0500	88	540	12	35	95	153	32	low	warm	OK	24	60	80	81	OK	80	69	9	15	40	39	32		
0600	[illegible]	540	12	31	96	174	32	OK	[illegible]	OK	[illegible]	58	82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
2000	94	540	8	29	106	165	28	OK	warm	OK	24	58	90	92	OK	86	71	7	18	41	40	31		
2100	93	540	10	31	107	165	30	OK	warm	OK	24	58	90	90	OK	84	72.5	9	22	42	39	32		
2200	93	540	10	30	106	162	31	OK	warm	OK	24	58	90	91	OK	84	70	11	23	41	41	33		
2300	93	540	7	30	120	168	28	OK	warm	OK	24	58	90	93	OK	84	72.5	10	18	40	39	32		
2400	93	540	6	30	115	152	26	OK	warm	OK	24	58	90	92	OK	84	71	7	16	39	38	31		

REMARKS: 0300 - Refrigerant shortage - checked and corrected leaky flange at suction line connection to compressor - added 30 lbs Freon-12

0400 - Expansion valve on #2 coil Meat Room #1 froze in open position. Flooding refrigerant to compressor - defrosted valve and connected dehydrator into system.

2000 - 3/8" frost on Meat Room #1 coils - Started defrosting.

2200 - Completed defrosting.

Figure 11–17.—Daily operating log for refrigeration equipment.

operated during the day, and how long each compressor and circulating water pump has been operated during the calendar month. Also, the amount of ice on hand and the amount of ice issued should be recorded.

The operating log of an air conditioning system is very much the same as the operating log for a refrigeration system. However, the operating data recorded on an air conditioning system log may be the average during the watch instead of the specific readings obtained each hour.

SAFETY PRECAUTIONS

Refrigerants are furnished in cylinders for use in shipboard refrigeration systems. The following precautions must be observed in the handling, use, and storage of these cylinders:

1. Never drop cylinders nor permit them to strike each other violently.
2. Never use a lifting magnet or a sling (rope or chain) when handling cylinders. A crane may be used if a safe cradle or platform is provided to hold the cylinders.
3. Caps provided for valve protection must be kept on cylinders except when the cylinders are being used.
4. Whenever refrigerant is discharged from a cylinder, the cylinder should be weighed immediately and the weight of the refrigerant remaining in the cylinder should be recorded.
5. Never attempt to mix gases in a cylinder.
6. NEVER put the wrong refrigerant into a refrigeration system! No refrigerant except the one for which the system was designed should ever be introduced into the system. In some cases, putting the wrong refrigerant into a system may cause a violent explosion.
7. When a cylinder has been emptied, close the cylinder valve immediately to prevent the entrance of

air, moisture, or dirt. Also, be sure to replace the valve protection cap.

8. Never use cylinders for any purpose other than their intended purpose. Do NOT use them as rollers, supports, etc.
9. Do NOT tamper with the safety devices in the valves or cylinders.
10. Open cylinder valves slowly. Never use wrenches or other tools except those provided by the manufacturer.
11. Make sure that the threads on regulators or other connections are the same as those on the cylinder valve outlets. Never force connections that do not fit.
12. Regulators and pressure gages provided for use with a particular gas must NOT be used on cylinders containing other gases.
13. Never attempt to repair or alter cylinders or valves.
14. Never fill Freon-12 cylinders beyond 80 percent of capacity.
15. Whenever possible, store cylinders in a cool, dry place, in an upright position. If the cylinders are exposed to excessive heat, a dangerous increase in pressure will occur. If cylinders must be stored in the open, take care that they are protected against extremes of weather. NEVER allow a cylinder to be subjected to a temperature above 125°F.
16. NEVER allow Freon to come in contact with a flame or red-hot metal! When exposed to excessively high temperatures, Freon breaks down into PHOSGENE gas, an extremely poisonous substance.

PERSONNEL PROTECTION AND FIRST AID

The greatest danger involved in the handling of Freon or in the servicing of refrigeration plants arises from

the fact that Freon is such a powerful freezing agent that even a very small amount can freeze the delicate tissues of the eye, causing permanent damage. For this reason, it is essential that goggles be worn by all personnel who may be exposed to Freon, particularly in its liquid form.

If Freon does get in the eyes, the person suffering the injury should receive medical treatment immediately in order to avoid permanent damage to the eyes. In the meantime, put drops of clean olive oil, mineral oil, or other nonirritating oil in the eyes, and MAKE SURE that the person does not rub his eyes. CAUTION: Do NOT use anything except clean, nonirritating oil for this type of eye injury.

If Freon comes in contact with the skin, it may cause frostbite. This injury should be treated as any other case of frostbite. Immerse the affected part in a warm bath for about 10 minutes, then dry carefully. Do NOT rub or massage the affected area.

Although Freon is generally classed as nontoxic, it IS poisonous in high concentrations such as might occur from excessive Freon leakage in a confined or poorly ventilated space. If a person should be overcome by Freon, remove him IMMEDIATELY to a well-ventilated place and get medical attention at the earliest opportunity. Watch his breathing. If the person is not breathing, give artificial respiration.

Additional information on first-aid treatment for exposure to refrigerants is given in the Navy training course, *Standard First Aid Training Course,* NavPers 10081.

QUIZ

1. The British thermal unit is a measure of which of the following?
   (a) Amount of heat.
   (b) Intensity of heat.
   (c) Specific heat.
   (d) Type of heat.

2. What definition of the British thermal unit may be used for all practical engineering purposes?

3. What term is used to describe heat that does NOT cause a change in temperature when absorbed by or removed from a substance?

4. What is sensible heat?

5. Is it necessary to increase the temperature of a boiling liquid, in order to vaporize the liquid?

6. If a substance has a specific heat of 0.25, how many Btu will be required to raise 1 pound of the substance 20° F?

7. What is a refrigeration ton?

8. How would you describe the basic purpose of the high-pressure side of a compression refrigeration system?

9. What temperature in a Freon-12 system controls the operation of the thermostatic expansion valve?

10. Why is a certain amount of superheat desirable in the refrigerant vapor leaving the evaporator?

11. What is the basic function of the compressor?

12. Why is a solenoid valve installed in the line leading to each evaporator, on multi-evaporator systems?

13. What valve keeps liquid refrigerant from flooding the evaporator and flowing to the compressor suction, if the compressor stops for any reason except normal suction pressure control?

14. Where are back-pressure regulating valves installed?

15. What control causes the compressor to go on or off, as required for normal operation of the refrigeration plant?

16. If the relief valve opens, where is the high-pressure vapor discharged?

17. Under what circumstances is it necessary to install a subcooler?

18. What is the greatest danger involved in the handling of Freon-12?

CHAPTER 12

AIR COMPRESSORS

As a Machinist's Mate you should have a thorough knowledge of air compressors, their construction, and care. There is hardly a station in the engineering spaces that is not directly dependent upon the ship's compressed air system, at least to some degree. It would be difficult to mention all the uses for compressed air aboard a modern Navy ship. Some of the outstanding uses for compressed air aboard ship are for operating pneumatic tools, sounding whistles and sirens, cleaning, ejecting gas from the ship's guns, starting diesel engines, charging and firing torpedoes, and catapulting airplanes. (On the Forrestal class carriers and some of the modernized carriers, air catapults have been replaced by steam catapults.) Since there are so many numerous uses for compressed air, several air compressing plants are installed aboard ship.

COMPRESSED AIR SYSTEMS

You will come in contact with three types of compressed air systems:

1. Low-pressure systems, from 100 to 150 psi.
2. Medium-pressure systems, 200 psi to 600 psi.
3. High-pressure systems, 3000 psi.

You may find all three types on some ships; on other ships, just the low and high; and on still other ships,

only the medium pressure. Pressures in certain lines of the high and medium pressure systems may be reduced with pressure-reducing devices to lower levels, for specific uses. The three systems are generally complete and independent, and supplied by separate main and auxiliary air compressors. A few older installations may be found, however, where the medium and low systems are cross-connected.

Low-Pressure Systems

Practically every surface ship of the Navy has a low-pressure ship's service air system installed. This system is ordinarily designed for a primary working pressure of 100 psi. Sometimes it is fed by the 200-psi compressor, which also feeds the gas ejection system. On repair ships and tenders, the system may be designed for a pressure of 125 psi. On later vessels, this system is supplied from a 150-psi, two-stage, air-cooled compressor. Where the capacity is relatively large, two-stage, water-cooled compressors are used. Some older ships are fitted with single-stage reciprocating steam-driven compressors for the low-pressure system. The latest design policy is to operate the same compressors for both the ship's service and the gas ejection systems.

The low-pressure system is intended to supply air for various purposes throughout the ship. It has outlets at all guns, and in the boiler rooms, enginerooms, evaporator rooms, refrigerating plant rooms, dynamo and electrical distribution rooms, motor generating rooms, and electrical, radio, and other workshop spaces. The general use of low-pressure air include the following:

1. Operating pneumatic tools (tube cleaners, paint chippers, drills, tappers, etc.).
2. Ejecting gases from the ship's guns.
3. Testing spaces for watertight integrity.
4. Cleaning fuel-oil atomizer tips in boiler rooms.
5. Cleaning pitometer log tubes.
6. Cleaning CO_2 indicator systems in boiler rooms.

7. Operating oil-burning forges, furnaces, and galley ranges.
8. Blowing down fuel hose.
9. Flight deck warning systems, horns, or whistles.
10. Cleaning aircraft engines and other aviation material.
11. Propeller shaft brakes on diesel ships.
12. Automatic combustion control.

Medium-Pressure Systems

In cases where it was not feasible to combine the ship's service and gas ejection systems, a separate gas ejecting compressed air system (designed for operating at 200 psi to 600 psi) was installed for removing gases and unburned solid matter from the ship's guns. The pressure depends upon the size of the battery of guns. Separate medium-pressure systems (designed for operating at 600 psi) are sometimes installed for starting large high-power diesel engines. Like the pneumatic main of the low-pressure system, the lines of these systems are run from the compressors to their ultimate destinations. The systems are arranged in duplicate, with appropriately located cross-connecting lines and valves, so that damaged sections can be isolated in battle and a requisite supply of compressed air maintained.

In nearly all cases, gas ejection air is also supplied by special flasks at the mounts. The flasks may be charged from the high pressure system, from which the air is bled off via reducing valves. This air in the flasks is usually enough to furnish ejection air during the firing of all ready service ammunition.

High-Pressure Systems

A high-pressure compressed air system, designed for a working pressure of 3000 psi, is also installed on practically all combat vessels. These high-pressure systems are used for charging and firing torpedoes, gas-ejecting reserve air banks, charging counter-recoil cylinders of

the ship's guns, operating aircraft catapults and arresting gear, and in some cases for starting high-power diesel engines. For some purposes, air is taken from the high pressure system through pressure-reducing valves.

AIR COMPRESSOR CLASSIFICATIONS AND TYPES

There are a number of variations in the design and construction of air compressors. You should be acquainted with the types of compressors in general use.

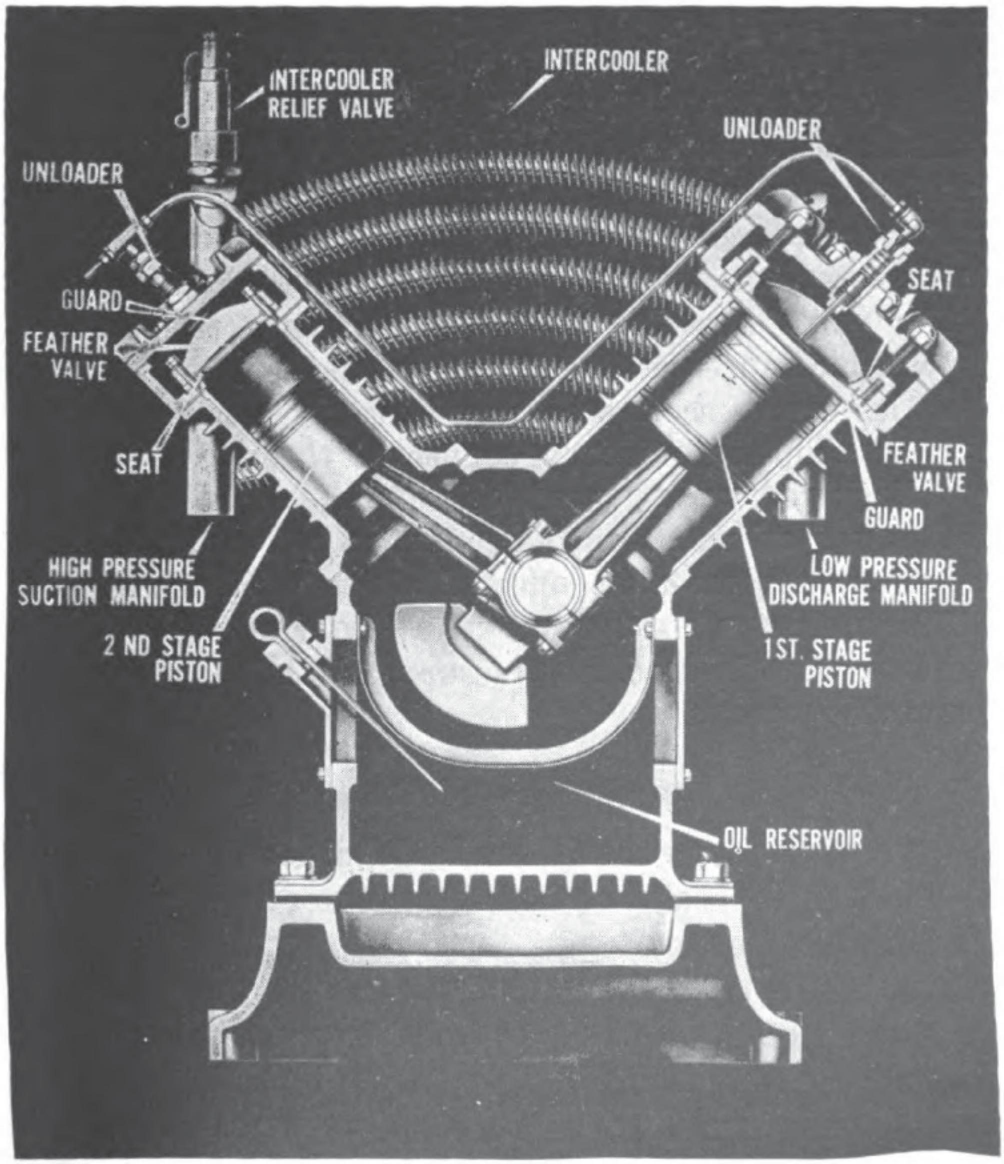


Figure 12–1.—A simple two-stage reciprocating low-pressure air compressor.

Classifications

To begin with, compressors may be classified—by major type; by type of prime mover; by type of transmission drive; and by magnitude of pressure.

The MAJOR TYPE CLASSIFICATION includes reciprocating, centrifugal, and rotary types. Most of the naval compressors are reciprocating (fig. 12–1), in which a piston compresses air in one or more cylinders. Centrifugal compressors are used primarily for delivering large quantities of air at a very low pressure; rotary compressors for supplying large volumes of air at slightly higher pressures.

The PRIME MOVER CLASSIFICATION (method of driving) includes compressors driven by electric motors, steam turbines, and internal combustion engines. The electric motor-driven compressors are in the majority. Steam turbines are mostly used for high-pressure compressors.

The DRIVE TRANSMISSION CLASSIFICATION (the method by which compressors are connected to the prime mover) includes compressors which are directly connected with a close coupling; directly connected through a flexible coupling; reduction-geared, belt-driven, or *en bloc,* with the power cylinders of the prime mover built into the compressor frame and connected to a common crankshaft.

The PRESSURE MAGNITUDE CLASSIFICATION includes the low-pressure, the medium-pressure, and the high-pressure types of compressors.

Compressor Definitions

You should know the following definitions because they are in common usage when referring to compressors and compressor operation.

ANGLE COMPRESSORS are of the multicylindrical type that have the axes of the cylinders at an angle to each other (fig. 12–2C). The more common types in Navy use are the VERTICAL V (2-cylinder) and VERTICAL W (3-cylinder).

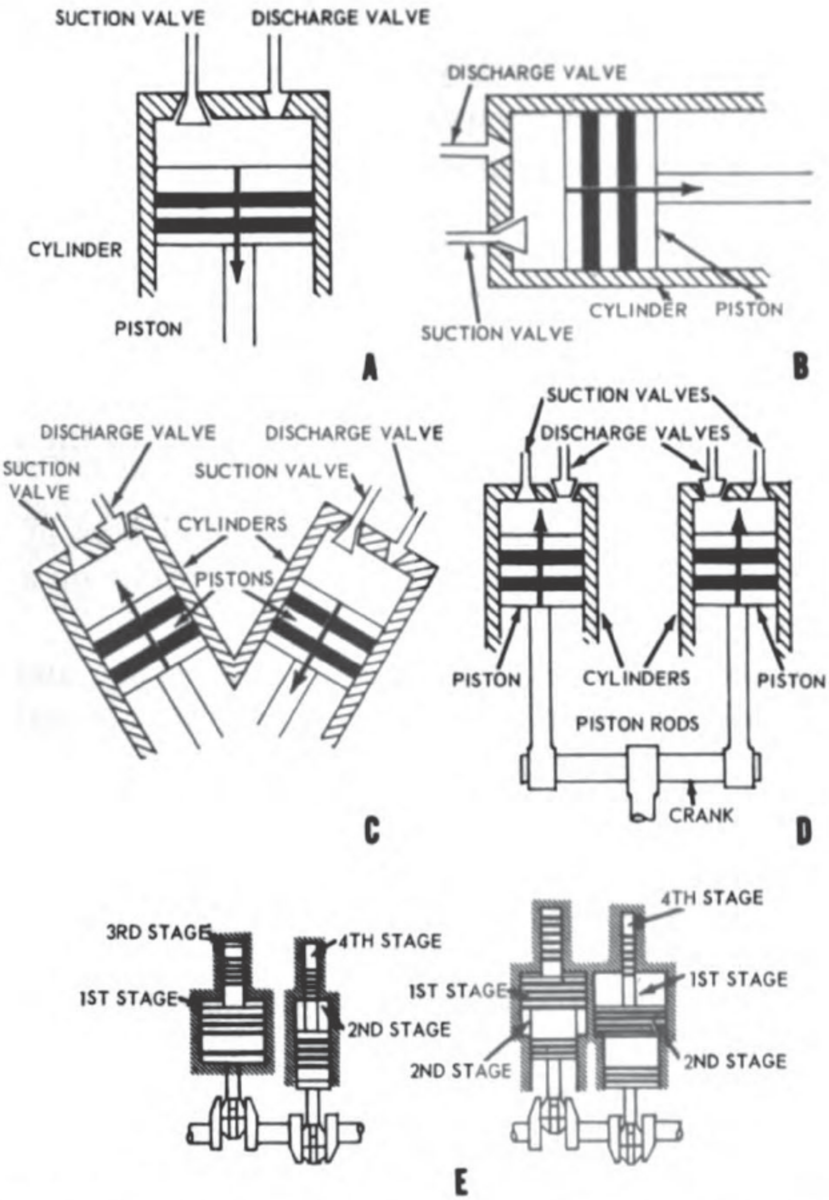


Figure 12–2.—Types of air compressors: (A) vertical, (B) horizontal, (C) angle, (D) duplex, (E) multi-stage.

ACTUAL CAPACITY is the quantity of air actually delivered or compressed. For low- and medium-pressure compressors the actual capacity is expressed in cubic feet of free air per minute. For high-pressure compressors it is expressed in cubic feet of compressed air per hour, at final discharge pressure but at intake temperature.

COMPRESSION RATIO is the ratio of absolute discharge

pressure to absolute intake pressure (either for the compressor as a unit or for any particular stage of the unit.)

COMPRESSOR DISPLACEMENT is the volume of air swept through by the first stage piston, or pistons, on compression strokes—expressed in cubic feet per minute. (In double acting compressors it is the volume swept through by both sides of the piston.)

DOUBLE-ACTING COMPRESSORS are those in which compression occurs on both strokes of the piston in a compressing element (fig. 12–2E), i.e., similar to the action in a double acting pump.

DUPLEX COMPRESSORS have two parallel sets of compressing elements driven by individual cranks on a common shaft (fig. 12–2D).

FREE AIR is air at the atmospheric pressure and temperature at the place where the compressor is installed.

HORIZONTAL COMPRESSORS are those which have the compressing elements in a horizontal plane (fig. 12–2B).

MULTISTAGE COMPRESSORS are those in which compression from initial to final pressure is completed in two or more stages (fig. 12–2E).

RATIO COMPRESSION is the ratio of absolute discharge pressure to absolute intake pressure. This may be further qualified as the ratio for any particular stage or to the compressor as a unit.

SINGLE-ACTING COMPRESSORS are those in which compression takes place on but one stroke per revolution in a compressing element (fig. 12–2A).

SINGLE-STAGE COMPRESSORS are those in which compression from initial to final pressure is complete in a single compressing element (fig. 12–2A).

TANDEM COMPRESSORS are those in which there is more than one stage of compression on each piston (fig. 12–2E); high pressure type compressors.

VERTICAL COMPRESSORS are those which have the compressing elements in a vertical plane (fig. 12–2A).

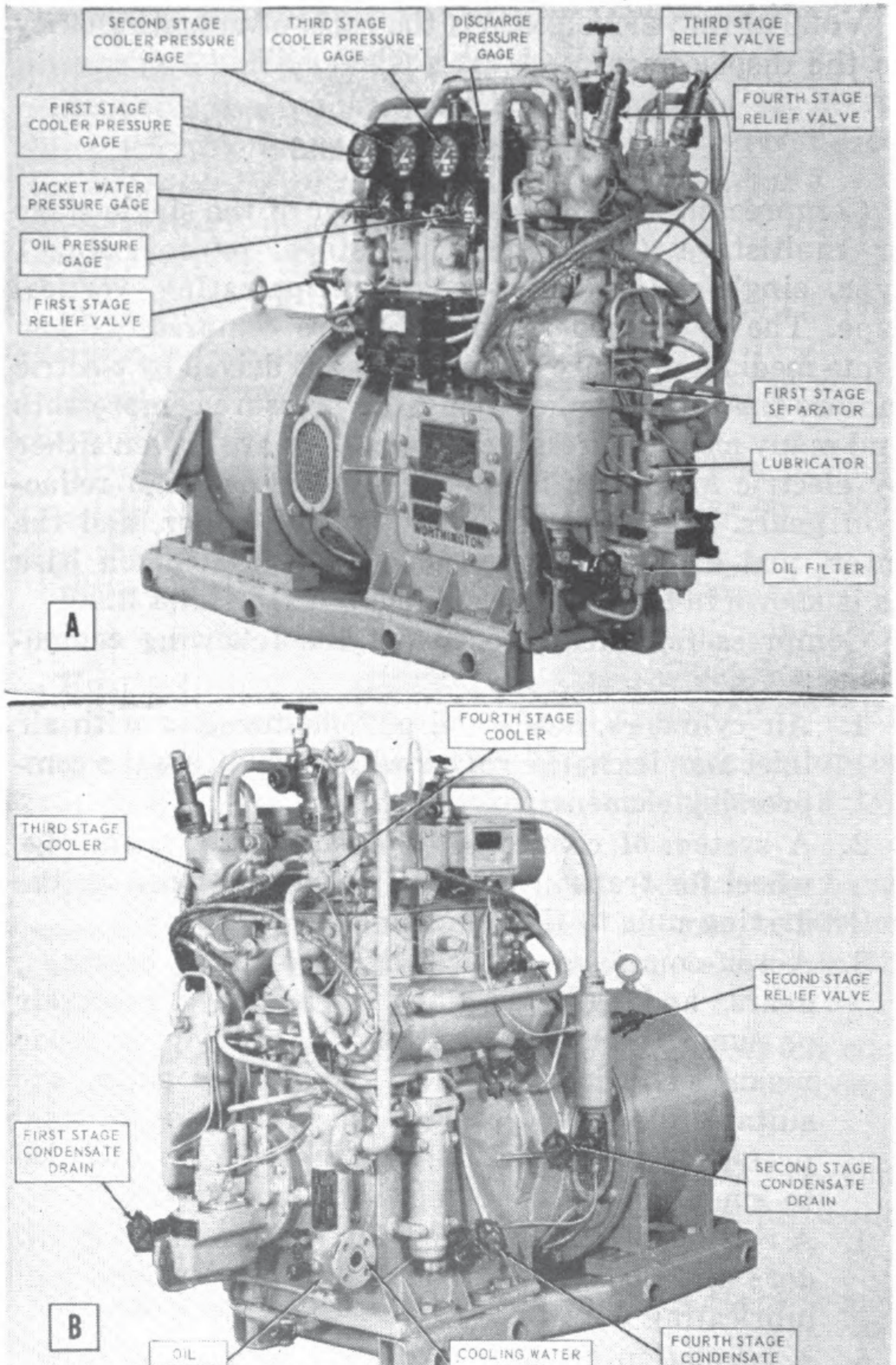
VOLUMETRIC EFFICIENCY is the ratio of actual capacity to the displacement.

COMPRESSOR DETAILS

Compressors in Navy use are either of the single-stage or multistage (two-stage, three-stage, or four-stage) type, single-acting, water-cooled, reciprocating, vertical type. The more modern low pressure compressors and some medium pressure compressors are driven by electric motors through V-belt drives. High pressure compressors and many medium pressure compressors are driven either by electric motors or by steam turbines through reduction gears. The compressor, its driving motor, and the inter- and after-cooler are mounted on a common base as is shown in the two views of figure 12–3A and B.

Compressors, briefly, consist of the following components:

1. Air cylinders, heads and pistons, together with air inlet and discharge valves which constitute the compressing element.
2. A system of connecting rods, crankshaft, and flywheel for transmitting the power developed by the driving unit to the air cylinder pistons.
3. A self-contained lubricating system for bearings, gears, and cylinder walls, including a reservoir or sump for the lubricating oil, a pump or other means of delivering oil to the various parts, and suitable filters and coolers. On high pressure compressors a separate force-feed lubricator is installed to supply oil to the compressor cylinders.
4. A cooling system for removing heat from the cylinders and heads, intercoolers and aftercoolers, and lubricating oil.
5. A regulation or control system designed to control the operation of the compressor so as to maintain the pressure, within a predetermined range, in the air system it serves.



Courtesy of Worthington Pump and Machinery Corp.

Figure 12–3.—Electric motor driven, four-stage, 3000 psig air compressor of the type installed on CVA 59 and 60.

6. An unloading system which automatically removes the compression load from the compressor while the unit is starting and automatically applies the load after the unit is up to operating speed.

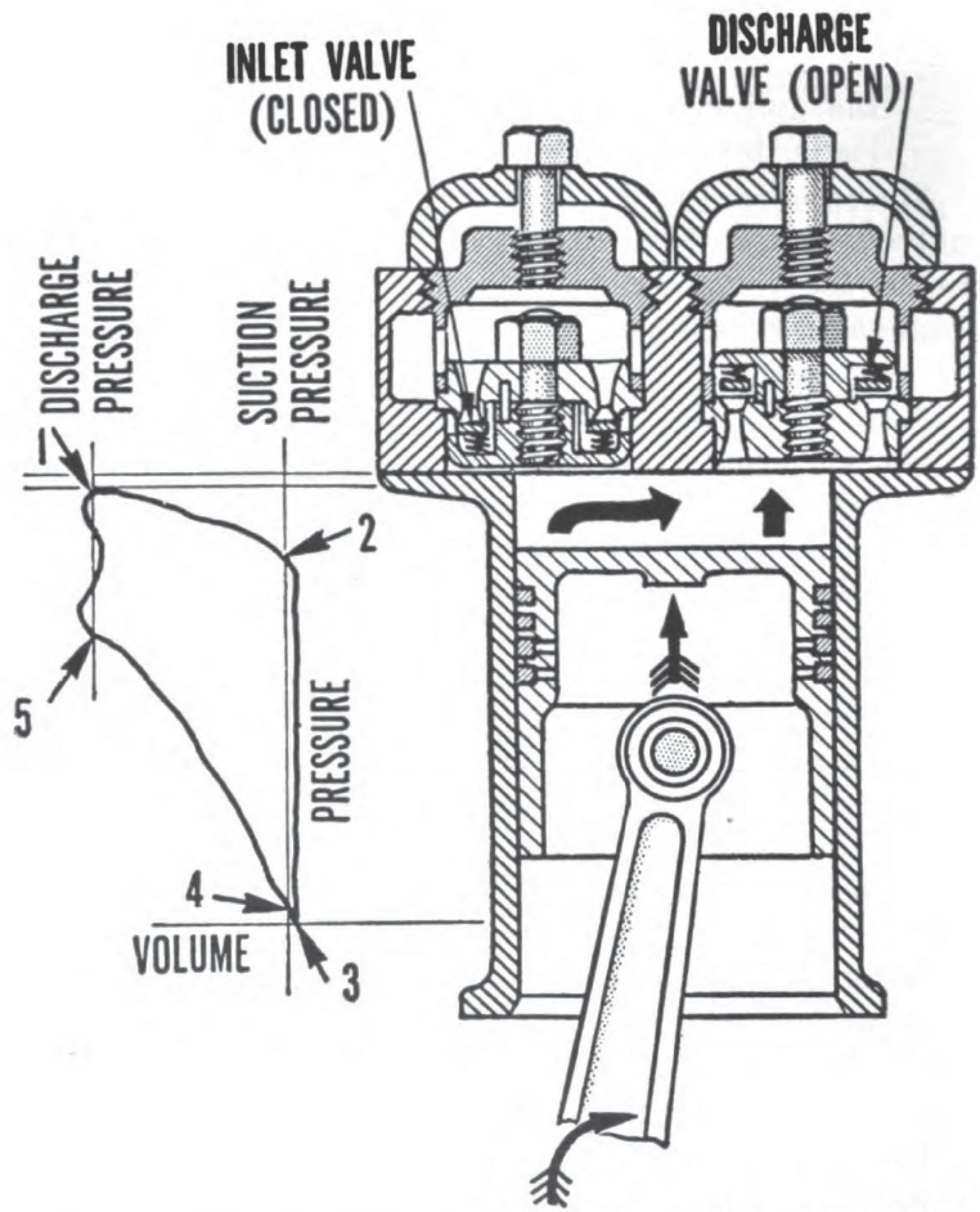
Air compressors are usually similar in construction and operation. Therefore, we shall discuss, in general terms, the operating cycles and systems of single-stage, single-acting compressors.

Compressor Strokes

The cycle of operation, or compression cycle, within an air compressor cylinder takes place with two strokes; the suction stroke and the compression stroke. How this cycle works is illustrated in figure 12–4, where you see a typical cylinder (with its piston and inlet and discharge valves) during a compression stroke. The pressure-volume relationship during this stroke is indicated graphically to the left of the diagram.

The SUCTION STROKE begins when the piston starts its downward motion. The air under pressure in the clearance space rapidly expands until the pressure falls below that on the opposite side of the inlet valve (points 1 and 2 in fig. 12–4). This difference in pressure causes the inlet valve to open, and air is admitted to the cylinder. The inflow of air continues until the piston reaches the bottom of the stroke (point 3).

The COMPRESSION STROKE begins when the piston starts upward, and compression is initiated. At point 4 the pressure is the same as that in the compressor intake, and the inlet valve now closes. Air is increasingly compressed as the piston moves upward, until the pressure in the cylinder becomes great enough to force open the discharge valve-against the pressure of the valve springs and discharge line pressure (point 5). From this point to the end of the compression stroke (point 1), the air which has been compressed in the cylinder is discharged through the open discharge valve at nearly constant pressure.

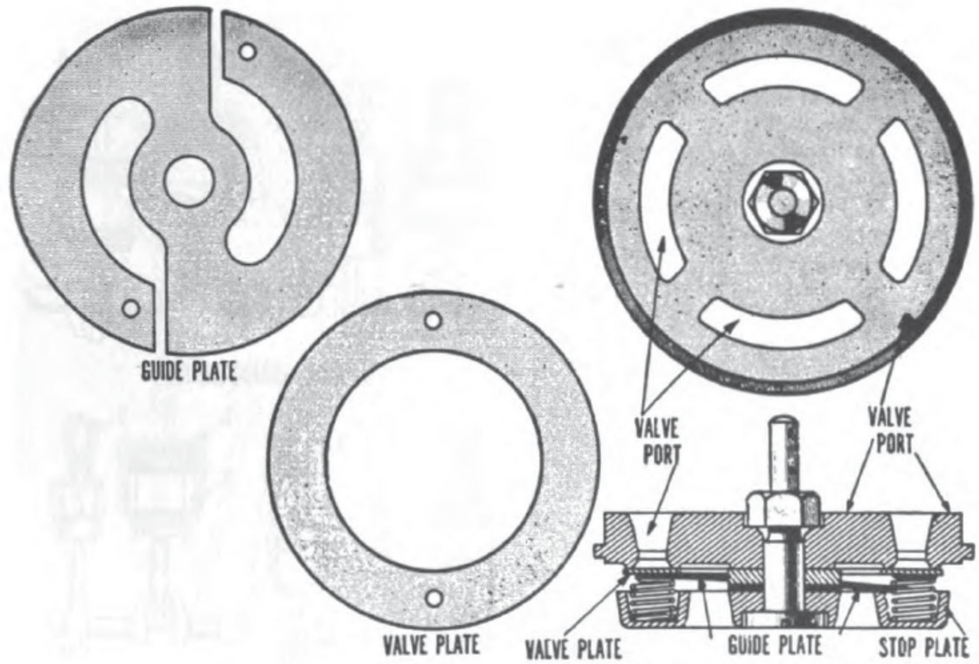


Courtesy of U. S. Naval Institute

Figure 12–4.—Typical single-acting air compressor cylinder and its related parts (showing compression stroke and accompanying pressure-volume relationship).

Compressing Elements

The AIR VALVES are a very vital part of the compressor, and more development work has been done on these parts than on any other parts of the compressor. Compressor valves on all modern ships (except some submarine high pressure compressors) are of the automatic type; that



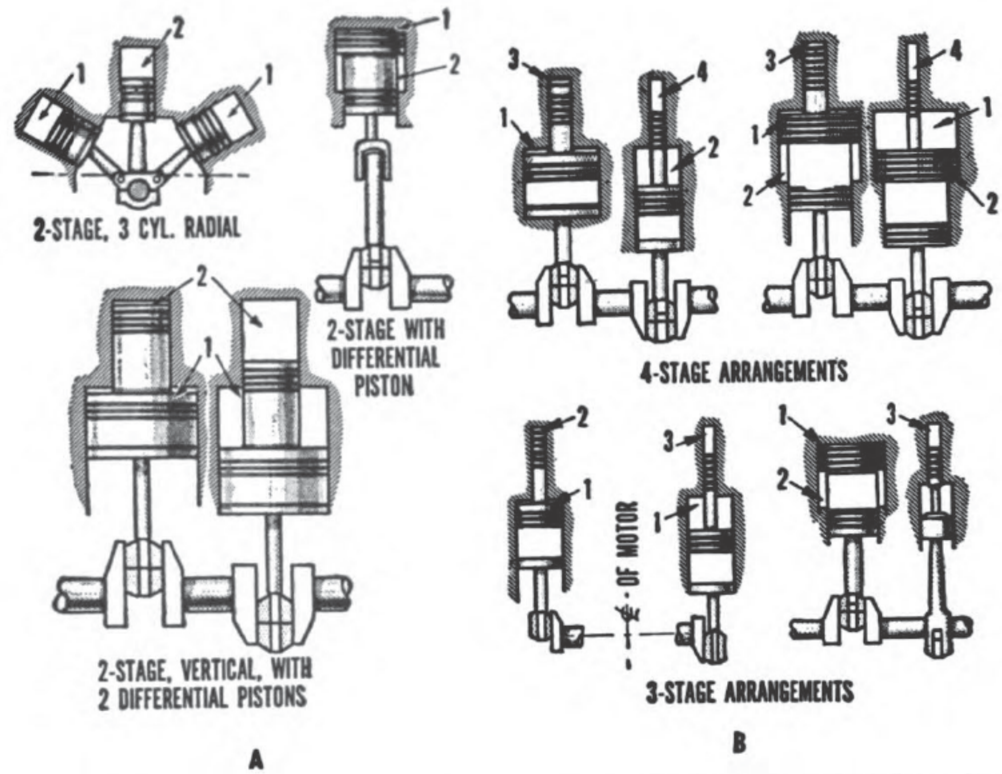
Courtesy of U. S. Naval Institute

Figure 12–5.—Diagram of thin-plate air compressor valve.

is, valve opening and closing is actuated solely by the difference in pressure between the air within the cylinder and the external air on the opposite sides of the valves (intake and discharge).

Thin-plate, low-lift valves are most generally used on all compressors, except for some light pressure cylinders. Figure 12–5 shows one design of a thin-plate valve. Note that it consists of a valve seat, valve plate, valve spring, and valve guide. The valve plate, being annular in shape, covers only the valve ports and is supplemented by a guide plate. The guide plate fits around the guide stem and is riveted to the valve plate. The guide plate is split, thus the outer portion is free to move up and down with the valve plate, while the center is held fast, keeping the valve plate centered. There are also other designs in use.

The AIR CYLINDERS are of various arrangements. The low pressure and medium pressure compressors may have the cylinders arranged in one of three ways, as illustrated in figure 12–6A—two-stage, three cylinder radial; two-



Courtesy of U. S. Naval Institute

Figure 12–6.—Air compressor cylinder arrangements: (A) low and medium pressure cylinders, (B) high pressure cylinders.

stage with differential pistons. The high pressure compressors may have either four-stage arrangements, or three-stage arrangements such as those shown in figure 12–6B. The numbers 1 through 4 in figure 12–6 represent the stage of compression.

The PISTONS may be of two types, trunk pistons and differential pistons. TRUNK PISTONS (figure 12–7A) are driven directly by the connecting rods. Since the upper end of a connecting rod is fitted directly to the piston wrist pin, there is a tendency for a piston to develop a side pressure against the cylinder walls. To distribute the side pressure over a wide area of the cylinder walls or liners, trunk pistons with long skirts are used. This type of piston tends to eliminate cylinder wall wear. DIFFERENTIAL PISTONS (fig. 12–7B) are modified trunk pistons having two or more different diameters. These pistons

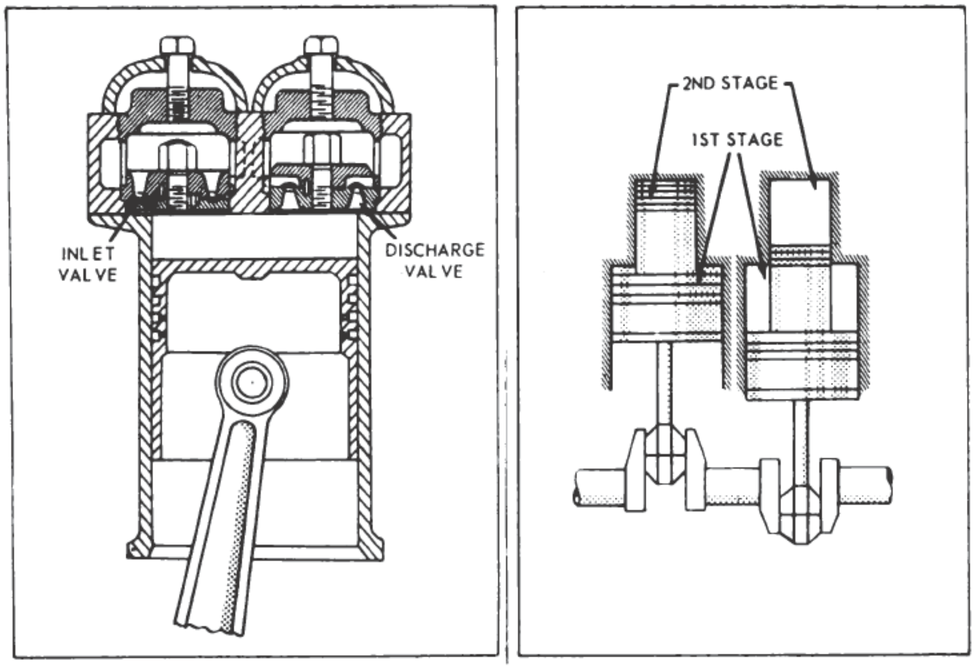


Figure 12–7.—Air compressor pistons; (A) trunk type, and (B) differential type.

are fitted into special cylinders which are arranged so that more than one stage of compression is served by one piston. The compression for one stage takes place over the piston crown; compression for the other stage(s) takes place in the annular space between the large and small diameters of the piston.

AIR FILTERS, fitted on air intake lines, must be kept in good condition so that air supplied to the compressor may be free from dust. Dust-laden air of sufficient concentration in a compressor may cause an explosion.

Power-Drive Transmission

The driving unit may be coupled to the compressor by one of several methods. However, these units are generally CLOSE COUPLED (both mounted on the same shaft). Flexible couplings are used where the speeds of the units are the same. Rigid couplings are still found on a few installations. Reduction gear drives are always used for turbine drives, and frequently used for electric or diesel drives.

The MAIN BEARINGS for the crankshafts are most often of the shell type and are fitted to the compressor base. Where the load is light, some of the newer small compressors have ball and roller bearings. Each shaft is fitted with a THRUST BEARING (usually of the ball bearing type) to overcome any thrust that may be developed by the driving unit or reduction gear and to ensure satisfactory operation when the ship is listing, rolling, or pitching in a seaway. Compressors fitted with taper roller main bearings do not require any additional thrust bearings.

Lubrication System

Lubrication of air compressor cylinders is generally accomplished by means of a mechanical forced-feed lubricator driven from a reciprocating or rotary part of the compressor. Oil is fed from the lubricator to each cylinder by a separate feed line. At the end of each feed line is a check valve that prevents compressed air from blowing back into the lubricator. Lubricators are equipped with a sight feed for each feed line. Lubrication begins automatically as the compressor starts up. The amount of oil fed to the cylinders depends upon the cylinder diameter, cylinder-wall temperature, and viscosity of the oil. In general, naval compressors that have cylinders up to 10 inches in diameter require 1 to 6 drops of oil feed per minute. Figure 12–8 illustrates the lube oil system of a high pressure air compressor.

On small low pressure and medium pressure compressors, the cylinders are lubricated by the splash method from dippers on the ends of connecting rods, instead of by a mechanical lubricator.

Lubrication of other parts of modern compressors such as bearings and reduction gears, is accomplished by an attached oil pump driven from the compressor shaft. This pump (usually gear type) draws oil from the reservoir in the compressor base and delivers it through a filter to an oil cooler. From the cooler, oil is distributed to the top of each main bearing to spray nozzles for re-

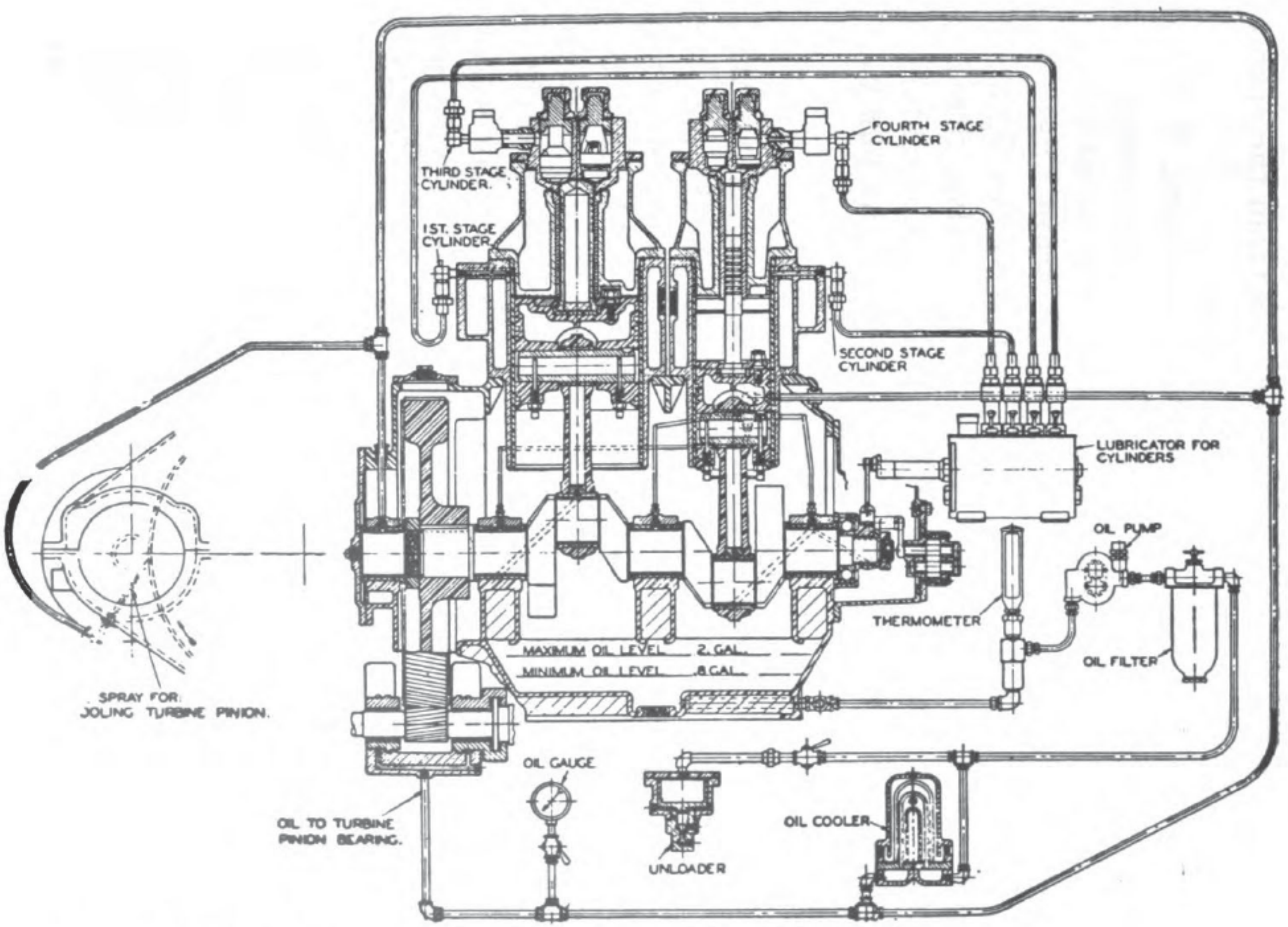


Figure 12-8.—Lube oil system of a typical multistage turbine-driven high pressure air compressor.

duction gears and to outboard bearings, as necessary. The crankshaft is drilled so that oil fed to the main bearings is picked up at the main bearing journals and carried to the crank-pin journals. The connecting rods contain a passage to carry lubricating oil from the crank-pin bearings up to the wrist-pin bushing.

As oil leaks out from the various bearings, it drips back to the reservoir in the base of the compressor and is ready to be recirculated. Oil from the outboard bearings is carried back to the base by the drain lines. The working pressure of the lube oil pumps varies from 15 to 40 psi with different designs. A relief valve, fitted to and set slightly above the working pressure of each pump, bypasses the discharge and suction sides of the pump.

Cooling Systems

All high pressure and medium pressure compressors are cooled by sea water supplied from the ship's fire, flushing, or water service mains. The cooling water is generally available to each unit through at least two sources. Compressors located outside the larger machinery spaces are generally equipped with an attached circulating water pump as a standby source of cooling water. Small low pressure compressors for ship's service and diesel engine starting are air-cooled by a fan mounted on, or driven from, a compressor shaft.

The path of water in the COOLING WATER SYSTEM of a typical four-stage compressor is illustrated in figure 12–9. Not all cooling water systems have identical paths of water flow, but in all systems it is important that the coldest water be available for circulation through the oil cooler. Valves are usually provided so that the water to the oil cooler can be controlled independently of the rest of the system. Thus oil temperature may be controlled without harmfully affecting other parts of the compressor. Next in importance are the intercoolers and aftercoolers, and lastly come the cylinder jackets and heads. The high pressure oil compressors require any-

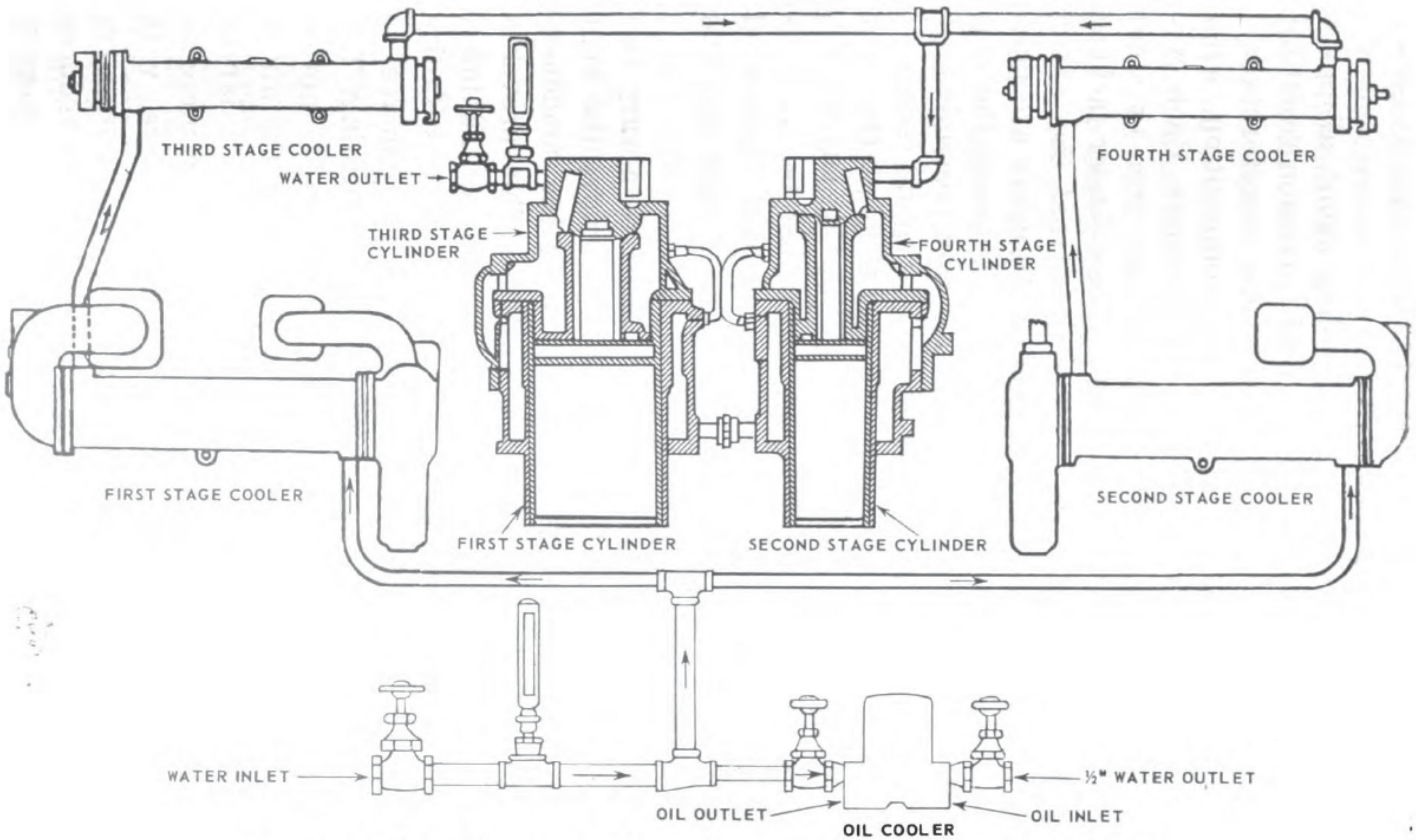


Figure 12-9.—Circulating water cooling system in a typical multistage air compressor.

where from 6 to 25 gallons of cooling water per minute, while medium pressure air compressors require from 10 to 20 gallons per minute.

Since sea water is used as the cooling agent, all parts of the circulating system must be of corrosion-resisting materials. The cylinders and heads are therefore composed of gun-metal or valve bronze composition, with water jackets cast integral with the cylinders. Each cylinder is fitted with a liner of special cast iron or steel to withstand the wear of the piston. The cylinder jackets are fitted with handholes and covers so that the water spaces may be inspected and cleaned. Jumpers are generally used to make water connections between the cylinders and heads, since these prevent any possibility of leakage into the compression spaces. In some compressors, however, the water passes directly through the joint between the cylinder and the head. With this latter type, extreme care must be taken to ensure that the joint is properly gasketed to prevent leakage which, if allowed to continue, would ruin both the cylinder liner and the piston rings.

The INTERCOOLERS and AFTERCOOLERS are a very important part of any compressor. They remove the heat generated during compression and cause the condensation of any vapor that may be present. This prevents unwanted accumulation at low points, water hammer, freezing or bursting of pipes in exposed locations, faulty operation of pneumatic tools, and possible damage to electrical apparatus where air is used for cleaning. The removal of heat is also required for economical compression. During compression the temperature of the air is increased, thus causing the air to expand to a larger volume which, in turn, requires a corresponding increase of work to compress it. Multistaging, therefore, with cooling of the air between stages, reduces the power requirement for a given capacity. The intercooling reduces the maximum temperature in each cylinder and thereby

reduces the amount of heat which must be removed by the water jacket at the cylinder. Also, the resulting lower temperature in the cylinder ensures good lubrication of the piston and the valves. Both the intercoolers and the aftercoolers are of the same general construction except that the aftercoolers are designed to withstand a higher working pressure than the intercoolers.

WATER-COOLED INTERCOOLERS may be of the straight tube and shell type or, if size permits, may be of the coil type. In compressors which have a discharge pressure below 250 psi, the air flows either through the tubes or over and around them. In higher pressure compressors (above 250 psi), the air flows through the tubes. Suitable baffles are provided in tubular coolers to deflect the air or water in its course through the cooler. In coil type coolers the air passes through the coil, with the water flowing around the outside. Suitable provision is made for the expansion of the tube nest.

AIR-COOLED INTERCOOLERS and AFTERCOOLERS may be of the radiator type or may consist of a bank of finned copper tubes located in the path of blast air supplied by the compressor fan.

Each intercooler and aftercooler is fitted with RELIEF VALVES on both the air and water sides. Water relief valves are generally set at 5 psi in excess of the maximum working pressure which may be applied to the system (155 psi for most compressors). The air relief valves must be kept set in accordance with directions given in the particular manufacturer's instruction book.

All intercoolers and aftercoolers are also fitted with MOISTURE SEPARATORS on the discharge side, to remove the condensed moisture and oil from the air stream. The separators are of a variety of designs. The removal of liquid being accomplished by centrifugal force, impact, or sudden changes in velocity of the air stream. Drains, generally of an automatic type, are provided on each separator for removing the water and oil.

Oil coolers are of the coil type, tube and shell type,

or of a variety of commercial types. External oil coolers are generally used but some naval compressors are fitted with a base type oil cooler in which cooling water is circulated through a coil placed in the oil reservoir. As with the intercoolers and aftercoolers, the materials of the tubes, coils, or cores of these coolers, are of a copper-nickel alloy with shell and tube sheets of bronze composition. On all later model compressors the circulating water system is so arranged that the quantity of cooling water passing through the oil cooler may be regulated without disturbing the quantity of water going to the cylinder jackets, intercoolers, or aftercoolers. Thermometers are fitted to the circulating water inlet and outlet connections, the intake and discharge of each stage of compression, the final air discharge, and to the oil reservoir.

Control Systems

The control system of an air compressor may include one or more of such devices as an automatic temperature shutdown device, start-stop control, constant speed control, dual control, and speed-pressure governor.

AUTOMATIC TEMPERATURE SHUTDOWN DEVICES are fitted on all recent designs of high pressure and medium pressure air compressors. Thus, if the cooling water temperature rises above a safe limit, the compressor will stop and will not restart automatically. Some compressors are fitted with a device that will shut down the compressor if the temperature of the air leaving the last stage of compression and before entering the aftercooler exceeds 400°F.

Control of regulating systems for naval compressors are mainly of the START-STOP TYPE, in which the compressor starts and stops automatically as the receiver pressure falls or rises within predetermined limits. On electrically driven compressors the system is very simple —the receiver pressure operates against a PRESSURE SWITCH that opens when the pressure upon it reaches a

given limit, and closes when the pressure drops a predetermined amount.

On steam-driven compressors the receiver pressure is piped to a CONTROL VALVE (also known as a pilot, trigger, or auxiliary valve) which, when the proper STOP PRESSURE is reached, admits air to a plunger connected with the turbine governor valve. This causes steam to be shut off and the compressor to come to rest. When the pressure falls to a predetermined level, the control valve closes, and the air acting upon the plunger is released by leakage or bleeding to the atmosphere. The steam is thereby permitted to flow through the governor valve and restart the turbine. Control is a bit more complicated on compressors starting at pressures of either 90 psi or 135 psi, as selected by the operator. On motor-driven units this is done by the use of two pressure switches with a three-way valve or cock, so that receiver pressure is admitted to the pressure switch which has the desired range of settings. Another control method is to direct the air from the receiver through a three-way valve to either of two control valves set for the respective range of pressures. To do this a single pipe is run from the control valves to the pressure switch, which is set to function at any desired pressure.

On turbine-driven units the arrangement is similar to that on the motor-driven, except that the combined line from the control valves is piped to the plunger acting on the turbine governor valves.

The CONSTANT SPEED CONTROL is a method of controlling the pressure in the air receiver by controlling the output of the compressor without stopping or changing the speed of the unit. This control is used on compressors that have a fairly constant demand for air, where frequent stopping and starting is inadvisable.

With a DUAL CONTROL, the compressor can be made to operate under either a start-stop or constant speed control at the will of the operator. This control has advantages on ships where the air mains must be kept under

pressure continuously for long periods of time. The constant speed control is selected when the air demand is continuous; the start-stop is used when the demand is light as at night.

Combined SPEED AND PRESSURE GOVERNORS are usually furnished for reciprocating steam-driven compressors, where neither the start-stop nor constant speed control is very satisfactory.

Unloading Systems

Air compressor unloading systems are installed for the removal of all but the friction loads on the compressors; that is, they automatically remove the compression load from the compressor while the unit is starting, and automatically apply the load after the unit is up to operating speed. For units having the start-stop control, the unloading system is distinct from the control system. For compressors equipped with the constant speed or dual controls, however, the unloading and control systems are integral parts of each other.

A detailed explanation cannot be given here for every type of unloading device used to unload air compressor cylinders, but you should know something about several of the unloading methods with which you will probably come in contact. These include closing or throttling the compressor intake, holding intake valves off their seats, relieving intercoolers to the atmosphere, relieving the final discharge to the atmosphere (or opening a bypass from the discharge to the intake), opening up cylinder clearance pockets, using miscellaneous constant speed unloading devices, and the employment of various combinations of these methods.

As an example of a typical compressor unloading device, consider the MAGNETIC TYPE UNLOADER. Figure 12–10 illustrates the unloader valve arrangement. This type of unloader consists of a solenoid-operated valve connected with the motor starter. When the compressor is at rest, the solenoid valve is deenergized, admitting air

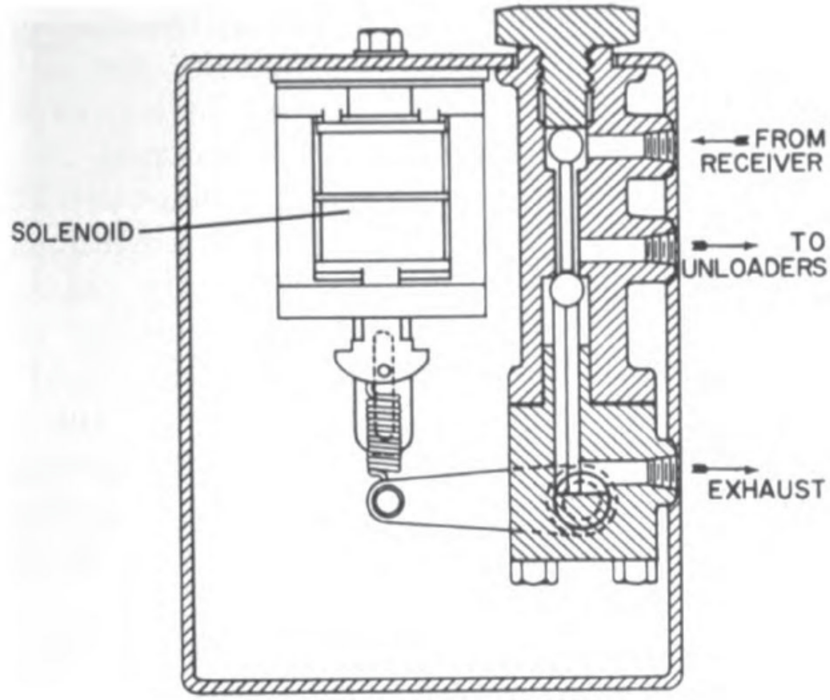


Figure 12-10.—Magnetic type unloader.

from the receiver to the unloading mechanism. When the compressor approximates normal speed, the solenoid valve is energized, releasing the pressure from the unloading mechanism and loading the compressor again.

For detailed information on the various unloading devices, refer to the pertinent manufacturers' instruction books on compressors installed on your ship.

Compressed Air Receivers

An air receiver or accumulator is installed in each space housing air compressors. The receiver acts as a supply tank and a storage tank. If demand is in excess of compression capacity, some of the stored air goes into the system. If demand is less than the compressor capacity, the excess is stored in the receiver or accumulator. Thus, in a compressed air system, the receiver functions to retard increase and decrease of pressure in the system and thereby the length of start-stop-start cycles. The volume of air receivers for low pressure and medium pressure compressors is approximately one-fifth of the

combined free air capacity per minute of the compressors located in a space. The receivers may be horizontal or vertical. The vertically mounted ones have convex bottoms to permit proper draining of accumulated moisture, oil, and foreign matter. All receivers include such fittings as inlet and outlet connections, drain connections and valves, connections for operating a line to compressor regulators, pressure gages, relief valves (set at 10 percent above normal working pressure of receiver), and handhole or manhole plates (depending upon the size of the receiver). The discharge line between the compressors and the receiver is as short and straight as possible to eliminate vibration due to pulsations of the air and to reduce pressure losses due to friction.

TYPICAL LOW-PRESSURE AIR COMPRESSOR

Having considered the various parts which comprise an air compressor, you may now follow the course of air through a typical compressor. Figure 12–11, as an example, illustrates various views of a radial, single-acting, three cylinder, two-stage, motor-driven low pressure air compressor with a V-belt connected flywheel, air-cooled cylinders, and air-cooled intercoolers and aftercoolers.

The free atmospheric air is drawn in through the two AIR INLET FILTERS and then through the inlet or SUCTION VALVES of the two FIRST-STAGE CYLINDERS as the two FIRST-STAGE PISTONS are on their downward or suction stroke. As the first-stage pistons are sent on their upward or compression stroke, by action of the CRANKSHAFT, the air is compressed in the two cylinders and forced out of the DISCHARGE VALVES. The FINS on the outside of the cylinders distribute the compression heat over a larger area, and therefore facilitate the removal of heat by the cooler air directed on them by the FLYWHEEL FAN.

The discharged compressed air is directed from the discharge valves on the first-stage cylinders, through the first-stage discharge line, to the aircooled INTERCOOLER.

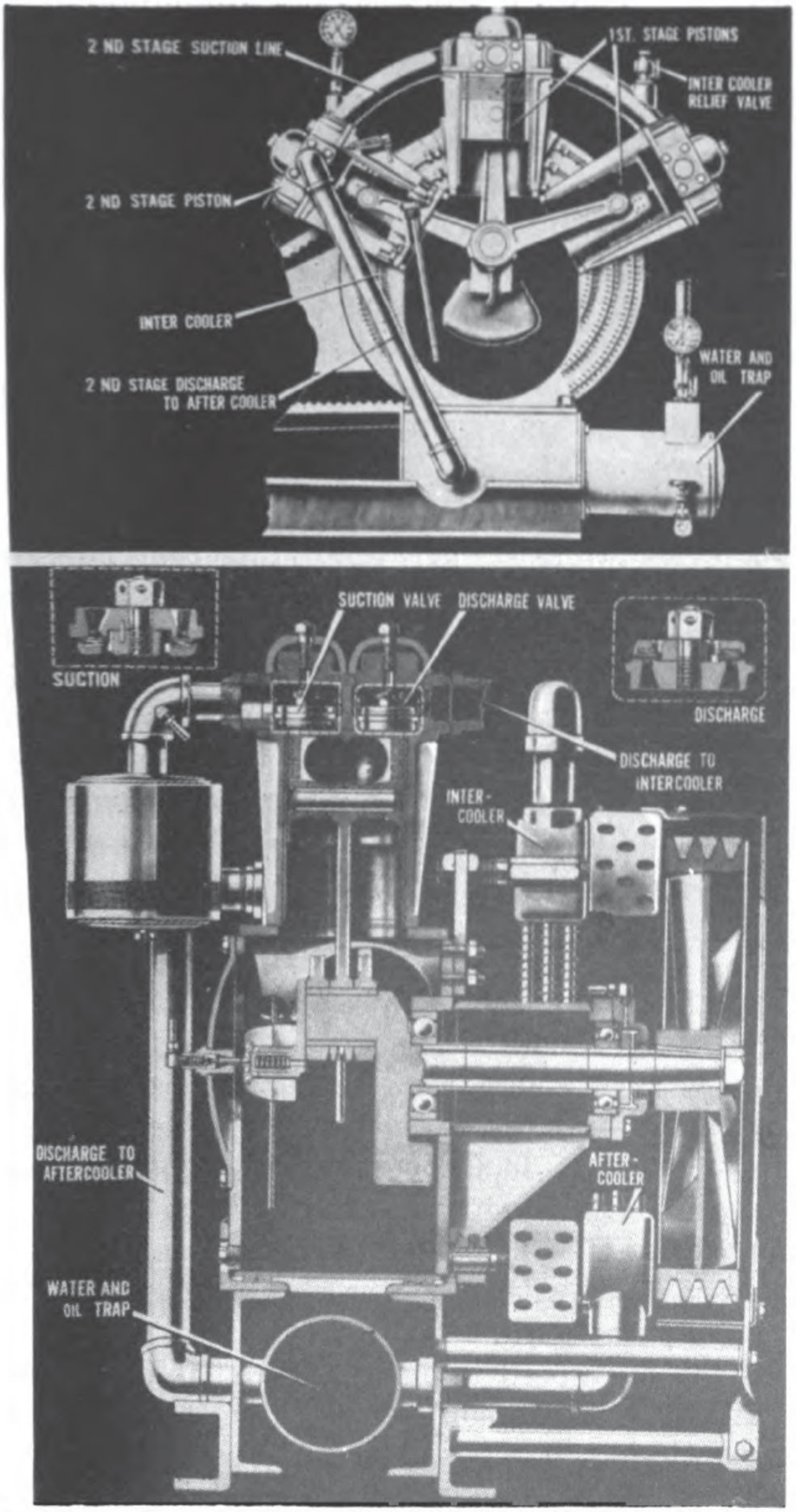


Figure 12–11.—Typical radial, single-acting, three cylinder, two-stage, motor-driven, air-cooled low pressure air compressor.

In the intercooler, the first-stage compressed air loses most of its heat by passing through coils surrounded by cooler air. From the intercooler, the compressed air is discharged, through the SECOND-STAGE SUCTION LINE, into the suction valve of the SECOND-STAGE CYLINDER. Here the air is further compressed to the set pressure, and then forced through the DISCHARGE VALVE, the SECOND-STAGE DISCHARGE LINE, and the WATER AND OIL TRAP, to the AFTERCOOLER, where the second-stage compression heat is removed. From the aftercooler, the compressed air is discharged into the AIR RECEIVER or reservoir.

OPERATING AN AIR COMPRESSOR

Before attempting to operate any air compressor for the first time, be sure that you are THOROUGHLY familiar with the machine. Study the accompanying manufacturer's instruction book. There are numerous varieties of compressors in naval use, so that it would be impossible in the limited space of this training course to present the operating procedures for each type of compressor. The following operating procedure is of a general nature.

Starting a Compressor

1. Visually check the compressor to determine that dirt has not blocked any of the lines. If necessary, remove dirt, waste, etc., from lines, valves, etc.
2. Inspect and clean the compressor exterior. Tighten any loose nuts, including foundation bolts. Remove any loose equipment that may be lying around.
3. Check the oil reservoirs and if necessary fill to the proper level with the correct grade of oil. Prime the oil pump and lubricator.
4. Set the overspeed tripping device (if provided).
5. Jack the compressor over by hand. (Be sure the power is off.)
6. Turn on cooling water to the cooling system. Vent the system.

7. Open all air system stop valves.
8. Open all separator drains and remove all accumulations of moisture or oil from the separators. These should remain open until the compressor is running.
9. When the compressor is up to normal speed, gradually put a load on the compressor by closing the separator drains and indicator cocks, taking care to close those connected with the first stage, and then those connected with the second stage. If fitted with a third and fourth stages, continue progressively through these two stages.

Operating a Compressor

1. After the compressor has been in operation a few minutes, recheck the oil level in the reservoirs, and if it has fallen appreciably, add sufficient oil to bring it to normal level.
2. Drain the receivers and accumulators at least once each watch.
3. Adjust the flow of cooling water so as to cool the air properly between stages. For compressors using salt water for cooling, the temperature of the outlet water must not be allowed to exceed 125°F.
4. Drain the intercooler and the aftercooler separators frequently and regularly.
5. Check the operation of all relief valves regularly —use the hand levers.
6. Read the pressure gages and thermometers regularly while the compressor is in operation.

Securing a Compressor

Securing is usually the reverse of the starting procedure.

MAINTENANCE OF AIR COMPRESSORS

To keep the ship's air compressors operating efficiently at all times, you must know what common troubles may be expected and their causes; how to care for the air

intakes; how to maintain and replace air valves; how to take care of the air cylinders and pistons; how to adjust bearings, wrist pins, couplings, etc.; and how to take care of the lubrication, cooling, control, and air systems.

Care of Air Intakes

A supply of clean, cool, dry air is essential to the satisfactory operation of compressors. To ensure this, the AIR INTAKE FILTERS must be regularly inspected and cleaned; otherwise, the filter becomes clogged and causes loss of capacity. To clean, remove the filter element and subject it to a jet of hot water or steam, or plunge it into a strong solution of sal soda. The filter body should be drained and replaced. If the filter is the oil-wetted type, dip it in clean medium grade oil and allow it to drain thoroughly before replacing the filter in the intake. Do not use gasoline or kerosene for cleaning filters; fumes may collect and explode in the compressor or receiver.

Care must also be taken to prevent entrance of rain or spray into INTAKE PIPES, and means should be provided for draining the intake pipe of any water which may collect. The lines should be as short and direct as possible.

Maintenance of Air Valves

Air inlet and discharge valves must be kept clean and in good working order. Leaky valves are generally dirty valves, and cause all kinds of trouble and capacity loss. The valves are removed by first loosening their set screws or clamps, and then removing their cover plates. Each valve and valve unloader, if fitted, may then be lifted out. Each valve should be marked, to make certain that it is returned to the same port from which it was removed. Valves removed for inspection should not be taken apart for cleaning unless their condition makes it necessary. Dirt or carbon in valve ports can usually be removed without taking the valve apart. This is done by soaking

the valves in kerosene, and then giving them a stiff brushing or a light scraping. Valve action should be tested by inserting a screw driver through the seat ports; the valve should lift and close freely.

Valve-seat gaskets and the valve cover-plate gaskets should be inspected BEFORE REPLACING AIR VALVES, as the installation of new gaskets may be necessary. Make certain the valves are replaced properly and in the right ports. Suction valves must open toward the center of the cylinder, and discharge valves must open away from the center. Very serious damage or loss in capacity may result from reversing the valves. Special locknuts are provided to seal against thread leakage at the valve set screw; or a turn of solder or fuse wire may be placed around the screw and set into a recess by the locking nut.

Maintenance of Cylinders and Pistons

The CYLINDERS AND PISTONS SHOULD BE INSPECTED only after the manufacturer's instruction manual has been consulted. Care should be taken when removing heads, particularly where metal-to-metal points are involved, to prevent damage to the joint. Where joints are fitted with a gasket, these can occasionally be saved by running a knife blade in between the gasket and head, after the head has been lifted not over one-fourth inch.

If a REPLACEMENT OF PISTON RINGS is required because of their being worn or broken, accurate measurements of the cylinder liners should be taken. Standard size rings may be used in oversize cylinders if the oversize does not exceed 0.003 of an inch per inch of cylinder diameter. The LINER may also need to be replaced if it is badly worn or out of round. When replacing piston rings, first fit them to the cylinder to check for proper end clearance. File the ends, if necessary, to make them fit. The side clearance of the rings should be such that the rings will fall easily into the piston grooves, which should be deep enough for the ring thickness. Ring splits should be staggered. After assembly of the piston, wire the rings

tight with a soft copper wire, so that they will enter the bore easily. This wire can be removed through the valve ports after the ring has started into the cylinder bore.

When REASSEMBLING THE AIR CYLINDERS and heads, be sure they are all drawn down evenly, especially on multistage compressors where the heads contain cylinders for third and fourth stages. Otherwise, excess wear on the cylinders and pistons will result.

When a compressor piston has been replaced, the PISTON END CLEARANCE must be checked. This is done by inserting a lead wire through a valve port or indicator connection. Jack the compressor over. When the piston has moved to the end of its stroke, the lead will be flattened to the exact amount of clearance. The wire should be long enough to permit a reading near the center of the piston. These readings should also be taken after any adjustment or replacement of the main, crank-pin, wrist-pin, or crosshead bearings. Methods of adjusting the clearances vary in accordance with compressor design; consult the manufacturer's instruction book for this adjustment.

Miscellaneous Adjustments

Other miscellaneous adjustments required from time to time on compressors include those pertaining to wrist pins, crosshead shoes, reduction gears, couplings, and V-belt drives. The manufacturer's instruction book will give you specific information for the care, adjustment, and replacement of all fitted bearings. Refer to the manufacturer's instruction book for detailed and specific information regarding when and how to make these adjustments.

WRIST PIN BUSHINGS are *replaced when* necessary. This is done when they are worn to the point of becoming noisy. In making a replacement, be sure the oil hole in the bushing is properly lined up with the oil hole in the connecting rod. After being pressed into the rod, the new bushing must be reamed.

CROSSHEAD SHOES are provided with shim or wedge adjustment. Wear should be slight, but adjustments should be made when the travel of the piston rod causes a movement in the stuffing boxes.

Alinements of REDUCTION GEARS AND PINIONS should be checked periodically, especially on a new compressor. Misalinement may be caused later by settling, straining, or springing of foundations; pipe strains on turbine-driven compressors; bearing wear; or springing due to heat from a turbine.

FLEXIBLE COUPLINGS require very little maintenance when properly lined up. Some types require occasional lubrication to prevent excessive wear of springs or bushings. A noisy coupling is an indication that the bushing is worn and requires replacement.

V-BELT DRIVES require adjustment for belt tension. Belts generally stretch slightly during the first few months of use. A loose belt will slip on the motor pulley and cause undue heating and wear on the belt. A tight belt will overload the bearings. Belts should be protected against oil, and from temperatures above 130°F, to prevent rapid deterioration. V-belts are usually installed in sets of two or three. If a single belt is worn or deteriorated, then the complete set should be replaced. This replacement of a complete set assures that the belts will each carry their share of the load.

Care of Lubrication System

Proper care of a compressor lubrication system includes the following procedures:

1. Keeping the oil at a normal level in the reservoir at all times, to maintain proper oil temperature.
2. Changing crankcase oil periodically, and at the same time cleaning and flushing the crankcase and cleaning the oil filter.
3. Maintaining proper lube-oil pressure, by keeping oil pump in good working order and adjusting the bypass relief valve.

4. Keeping the oil cooler free from leaks (since pressure on water side exceeds that of the oil), to prevent oil contamination and emulsification.
5. Occasionally replenishing transparent liquid (glycerine and water) in lubricator sight-feeds.
6. Properly adjusting the lubricator for the specified quantity of oil feed.

Care of Cooling System

Proper care of a compressor cooling system includes the following inspections and maintenance procedures.

1. Periodically inspecting the intercoolers and aftercoolers.
2. Removing collections of gummy oils or tarry substances from the cooler tubes by washing tube nests with a suitable solvent. See that they are thoroughly dry before reassembling.
3. Correcting any leakage in tube nests, to prevent leaks of water into the compressor while secured, or leaks of air into water side during operation.
4. Inspecting and cleaning cylinder water jackets periodically with a cleaning nozzle.

When FILLING THE COOLING WATER SYSTEM after the compressor has been drained, open the water inlet valve slightly to allow the water to rise slowly in the cooler shells and water jackets. Vent valves fitted to the water spaces should be opened to permit entrapped air to escape, and to remove any air pockets.

Care of Control Devices

Because of the great variety of REGULATING AND UNLOADING DEVICES employed on compressors, you will have to consult the manufacturer's instruction book for information regarding the adjustment of these devices on particular compressors.

If a CONTROL VALVE fails to work properly, it should be taken apart and cleaned. Some valves are fitted with a filter filled with a sponge or woolen yarn to prevent particles of dust or grit from being carried into the valve

chamber, and to remove gummy deposits from oil used in compressor cylinders. When repacking, use only genuine wool. Cotton will pack and stop the air flow. RELIEF VALVES, very important for safe compressor operation, should be set as specified by the manufacturer, test-lifted by hand each time the compressor is started, and periodically tested by raising the pressure in the spaces to which they are attached (to check the setting).

Care of Air Systems

All compressor air system air flasks, separators, and piping aboard surface vessels, must be inspected every three months to ascertain whether there is an external corrosion or damage. The inspection results must be recorded in the Material History Record. High pressure air flasks and separators should be inspected internally for the presence of corrosion. This inspection should be made at an interval of no more than six years and at intervals of approximately three years thereafter.

ROUTINE TESTS

The following compressor tests are to be made and the results recorded in the Engineering Log.

DAILY.—Jack over all compressors by hand.

WEEKLY.—Run the compressors by power.

MONTHLY.—Inspect all air-inlet and discharge valves.

QUARTERLY.—Measure the electric power required to start and operate motor-driven compressors. If this is excessive, overhaul is necessary.

Make a general inspection of the compressor including valves, bearings, filters, inter- and after-condensers, air passages, and cylinders. Unless inspection of the cylinder and other conditions indicate the necessity, pulling of pistons and removal of connecting rods are not required quarterly.

Test operation and setting of speed limiting and emergency overspeed tripping devices, if provided.

ANNUALLY.—Test all parts of the air system under full pressure. Calibrate all pressure gages.

SHIPYARD OVERHAUL.—Completely disassemble compressor for thorough inspection. Pressure test all relief valves. Inspect interior of air receivers.

SAFETY PRECAUTIONS

1. Explosions may be caused by dust-laden air, presence of oil vapor in the compressor or receiver, and by leaky or dirty valves resulting in abnormally high temperatures.
2. Every effort must be made to have only clean, dry air at the compressor intake.
3. Never use benzine, kerosene, or other light oils to clean compressor intake filters, cylinders, or air passages. These oils vaporize easily and will form a highly explosive mixture with the air under compression.
4. Secure a compressor immediately if it is observed that the temperature of the air discharged from any stage rises unduly or exceeds 400°F.
5. Never leave the compressor station after starting the compressor unless you are sure that the control, unloading, and governing devices are operating properly.
6. To prevent damage due to overheating, compressors must not be run at excessive speeds. Proper cooling water circulation must be maintained.
7. If the compressor is to remain idle for any length of time, and is in an exposed position in freezing weather, the compressor circulating water system should be thoroughly drained.
8. Before working on a compressor make sure that the compressor is secured and cannot start automatically or accidentally. The compressor should be blown down completely, all valves (including control or unloading valves) between the compressor and the receiver should be secured. Leave the pressure gages open at all times.

QUIZ

1. Air at 3000 psi is carried in which shipboard compress d air system?
2. If a ship has only a medium-pressure air compressor, how is low-pressure air made available for pneumatic tools?
3. On modern ships, are the three compressed air systems generally cross-connected, or are they completely independent?
4. Which of the valves in a single acting compressor open on the downward stroke of the piston?
5. How is compressor capacity expressed for low pressure and medium pressure compressors? For high pressure compressors?
6. How are low pressure and most medium pressure air compressors driven aboard modern naval vessels?
7. What is the purpose of the long skirt on a trunk-type piston?
8. In general, what rate of lubrication feed is required by air compressor cylinders measuring up to 10 inches in diameter?
9. What is a cooler called if it is located between the second and third stages of an air compressor?
10. What are two important functions of an air compressor cooler?
11. What is the source of moisture that is picked up by the moisture separator?
12. The pumping action of a compressor piston may impart pulsations to the compressed air. Which unit of the compressor air system functions to dissipate these pulsations?
13. Prior to jacking over a compressor, what precaution should be taken?
14. What does a noisy flexible coupling indicate?
15. How often should air compressor systems be inspected for external corrosion and damage?
16. Why shouldn't benzine, kerosene, or light oils be used for cleaning compressor intake filters, cylinders, or air passages?
17. At least how often should the receivers and accumulators be drained?
18. How may dirty valves affect compressor operations?

CHAPTER 13

STEERING ENGINES, DECK MACHINERY AND ELEVATORS

Besides heating, ventilating, air conditioning, and emergency diesel-driven equipment, there are a number of other AUXILIARY UNITS OUTSIDE THE REGULAR ENGINEERING SPACES which you will be expected to know something about. This machinery includes the steering gear, anchor windlasses, deck winches, capstans, cranes, elevators, pumps, and miscellaneous remotely-controlled valves. You will not be concerned with the operation of most of this equipment, but you must know how to maintain the units in good operating condition. Most of this auxiliary equipment operates hydraulically.

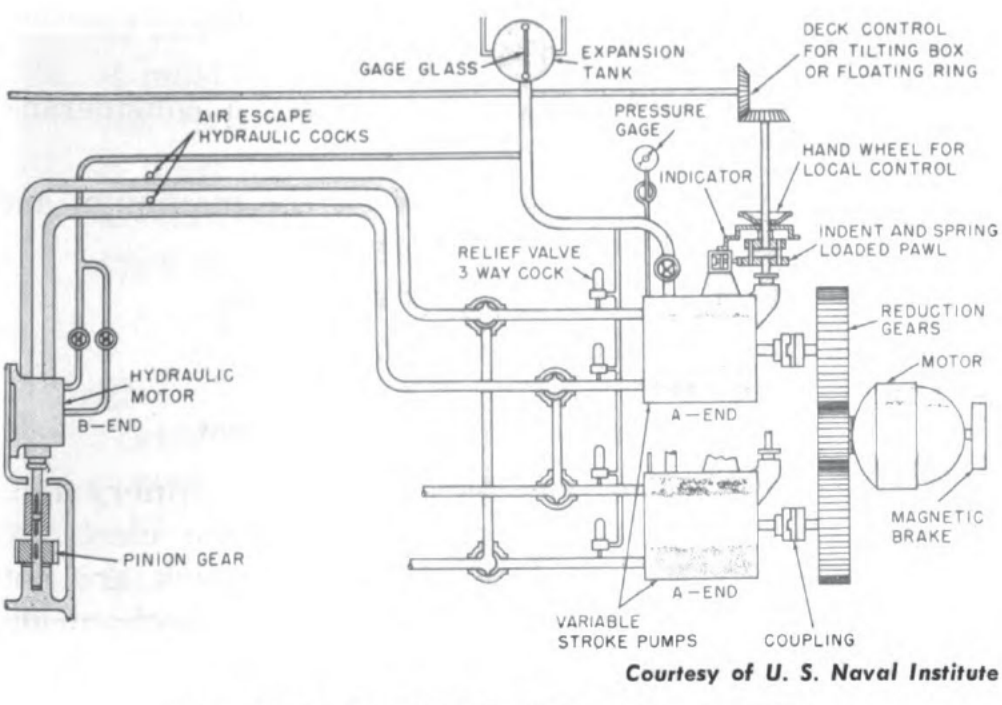
It may be helpful for you at this point to review the chapter on hydraulic principles and machinery in Navy training course *Basic Machines,* NavPers 10624.

Some pieces of the auxiliary machinery, such as the anchor windlasses, are required to operate at variable speeds over a considerable range. In addition, there must be close control of speed between maximum and minimum limits. A common requirement of this auxiliary machinery is high starting torque and ability to accelerate to maximum speed quickly. To meet these requirements in modern Navy vessels, the electrohydraulic drive has been adopted. Because some of the older ships are still being used, we will also discuss electromechanical and steam-driven auxiliary machinery.

Rotary motion, transmitted by hydraulic equipment is accomplished by use of a combination of a hydraulic pump—"A-end," and a hydraulic motor—"B-end" (fig. 13–1). For a discussion of the operation of this pump (axial-piston variable stroke pump) refer back to chapter 8, Pumps, of this training course.

Since the B-end is already on stroke, it will be made to rotate by the hydraulic force of the oil acting on the pistons. Movement of the pistons' A-end is controlled by a tilt box in which the socket ring is mounted.

By moving the tilt box one way or another, and by the amount of angle at which the tilt box is placed, the length of piston movement is controlled. This in turn controls the amount of fluid flow. The A-end is always in motion, but with the tilt box in a neutral or vertical position no oil is pumped to the B-end. Any movement of the tilt box, regardless of how slight, causes pumping action to start, and therefore immediate action in the B-end.



Courtesy of U. S. Naval Institute

Figure 13–1.—Typical hydraulic power transmission.

When reciprocating motion is desired, such as will be found in a steering gear, the B-end is replaced by a piston or ram. The force of the hydraulic fluid causes the movement of the piston or ram. The tilt box in the A-end can be controlled either locally as on the anchor windlass or by remote control as on the steering gear.

Advantages of Electrohydraulic Machinery

Some of the major advantages of hydraulic machinery are listed below:

1. Tubing, which can readily transmit fluids around corners, is used to conduct the liquid which transmits the force.
2. Very little space is required for the tubing.
3. Few moving parts are required.
4. Efficiency of the machines is often as high as from 80 to 95 percent.

Because of these advantages, the electrohydraulic type of drive very efficiently meets the operating requirements of modern naval machinery. These requirements, for such auxiliary machinery as the steering gear and the anchor windlasses, include the following:

1. Operation at variable speeds over a considerable range.
2. Close control of speed between the maximum and minimum limits.
3. Operation with a high starting torque.
4. Ability to accelerate quickly.

Nonhydraulic Auxiliary Equipment

While a large majority of the auxiliary machinery units outside the regular engineering spaces are electrohydraulically driven, there are also some which are not. Some machinery components are electromechanically driven, and some steam driven. Auxiliary machinery of this last type are found mostly on the older ships.

STEERING GEARS AND THEIR REMOTE CONTROLS

Strictly speaking, the steering gear is the mechanism which transmits power from the steering engine to the rudder stock, though the term is frequently used to include the driving engine and the transmitting mechanism. The following three types of steering gears may be found:

1. Electrohydraulic.
2. Electromechanical.
3. Steam driven.

In modern naval vessels, however, practically all steering mechanisms are hydraulically driven. Constant-speed electric motors drive variable-stroke rotary pumps, which furnish the hydraulic power to steering gear ram cylinders.

Requirements of Steering Gears

The steering gear of your ship must have four very definite characteristics:

1. It must be rugged.
2. It must be as reliable and as simple in construction as practicable.
3. It must be designed so that the rudder cannot cause the control wheel or lever to be jammed.
4. It must have such a high mechanical advantage that a relatively small amount of input power will produce large rudder post torques.

Remote Control of Steering Gears

Control of the steering gear from the steering wheel on the bridge may be accomplished by any of the following remote control systems, although most modern naval vessels use the first one:

1. Electrically, by means of an alternating-current synchronous transmission system.
2. Hydraulically, by means of a hydraulic telemotor system.

3. ELECTRICALLY, by means of a direct-current pilot motor and its controller.
4. MECHANICALLY, by means of a shafting or wire rope from the steering station.

Alternating-Current Synchronous Transmission

The alternating-current synchronous transmission type of remote control consists of self-synchronous type transmitters located in the several steering stations, and controlled by the motion of the steering wheel, suitable electric leads, and a self-synchronous type receiver that is connected, through a differential type follow-up mechanism, to the control shaft of the variable-stroke hydraulic pumps. Motion of the steering wheel, which is mounted on an extension of the shaft of the transmitter rotor, is directly transmitted thereby to the steering engine control mechanisms—there to produce the desired rudder angle. The follow-up system maintains the movement of the rudder proportional to that of the steering wheel, so that rudder movement is thereby stopped as soon as the rudder matches each motion of the wheel. Electrical control cables between the pilot house and the steering room are generally installed in duplicate, port and starboard, with suitable selector switches provided in steering room and pilot house.

Hydraulic Telemotor Control

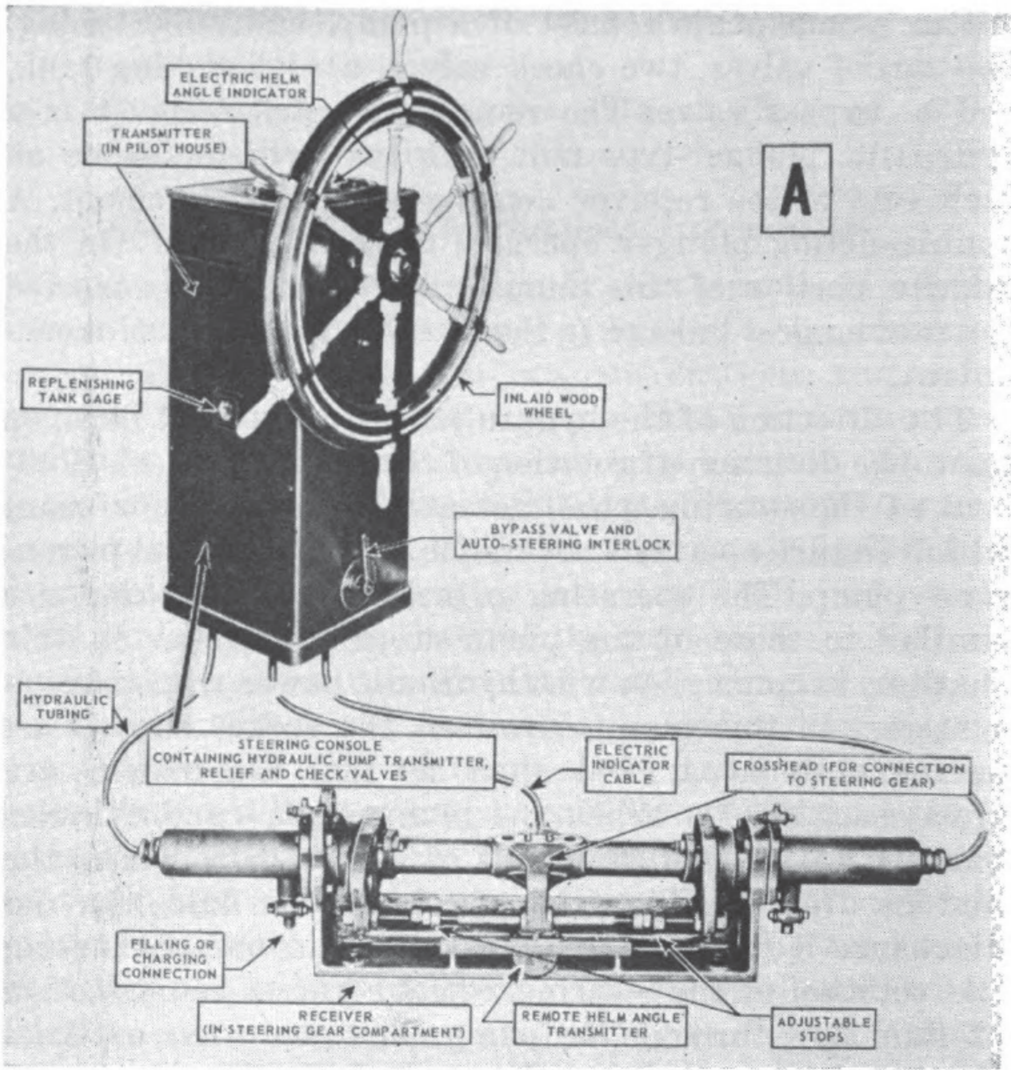
The hydraulic telemotor type of remote control (fig. 13–2) is found on many Navy auxiliary ships that are equipped with electrohydraulic steering engines. The system consists of a steering console (hydraulic transmitter) in the pilot house; a hydraulic receiver in the steering gear compartment, aft; and connecting hydraulic tubing. In addition, there is an electric cable which connects the helm angle transmitter on the receiver housing with the helm angle indicator on the steering console.

A hydraulic transmitter is located inside the steering console and under the steering wheel. Hydraulic trans-

mitter components consist of a pump, hydraulic tubing, two relief valves, two check valves, a replenishing tank, and a bypass valve. The remotely located receiver is a hydraulic plunger-type unit with two cylinders—one on each end of the receiver housing—in axial alinement. A double-acting plunger operates in the cylinders. On the middle portion of this plunger a crosshead is connected for mechanical linkage to the steering gear control mechanism.

The direction of the hydraulic fluid movement depends upon the direction of rotation of the steering wheel. Rotation of the steering wheel actuates bevel and spur gears which in turn operate a reversible, hydraulic, axial piston-type pump. The operating principles of this pump are similar to those of the pump described earlier in this chapter, in connection with hydraulic power transmission systems. In this pump, however, the socket ring is set permanently at a fixed angle so that the pistons are always on stroke. When the pump shaft (and cylinder barrel) are rotated by means of the steering wheel, the pistons draw fluid in from one hydraulic fluid line and discharge it to the other hydraulic fluid line. Reversing the rotation of the steering wheel reverses the direction of fluid flow through the pump. The pump has external check valves and piping for replenishing the hydraulic system from the tank. Relief valves and a bypass valve are also included, as well as vents for purging the system.

When the hydraulic pump shaft is rotated in one direction, the fluid output is discharged from one side of the pump to one of the receiver cylinders. In the other cylinder hydraulic fluid is displaced to the hydraulic pump. Thus the hydraulic fluid under pressure moves the receiver plungers and produces a linear movement of the crosshead. This motion is, in turn, transmitted to the connected steering gear control mechanism. Travel of the crosshead and plungers is limited by adjustable stops on the receiver housing. In figure 13–2, the solid arrows show direction of action for right rudder while the broken



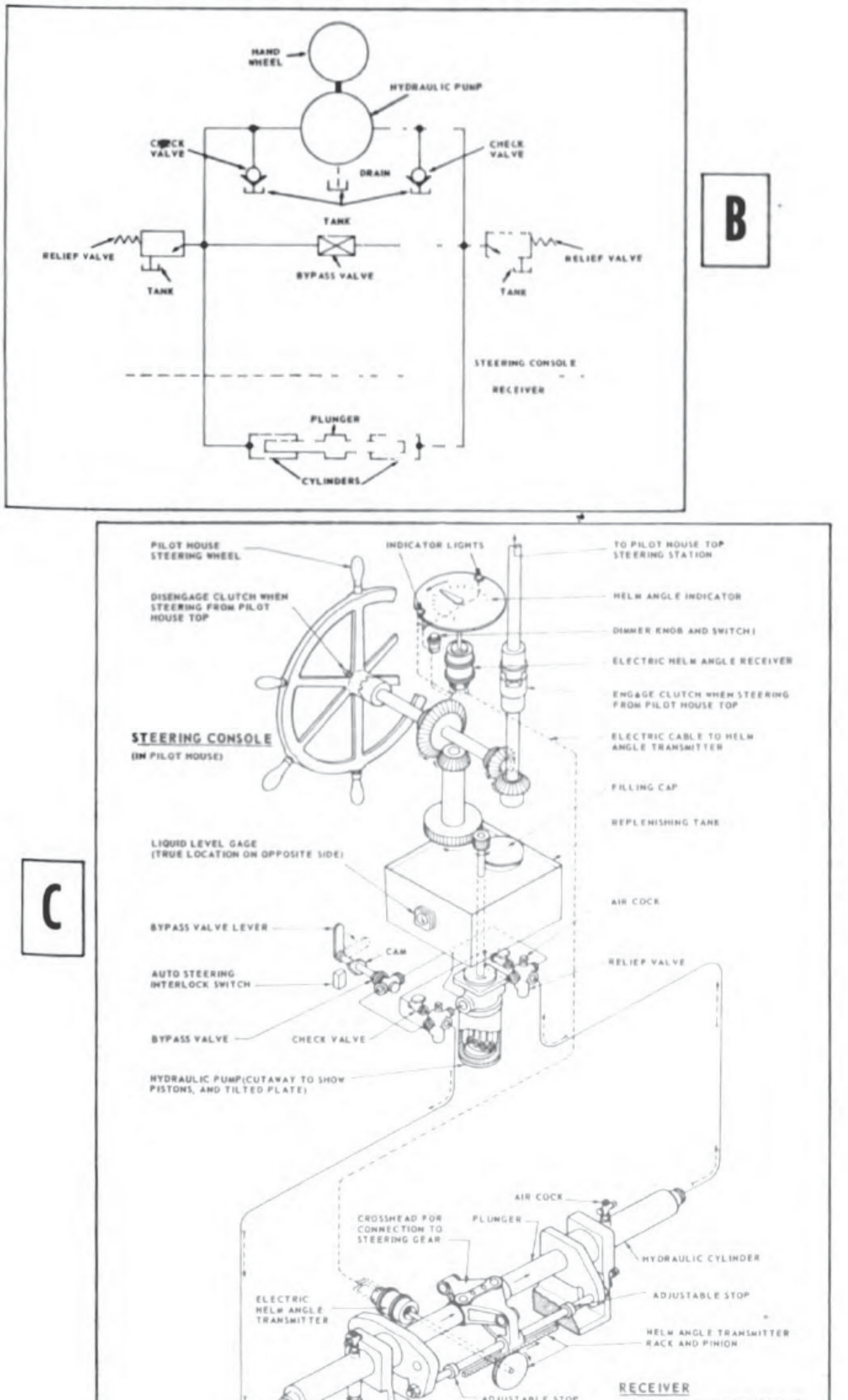
Courtesy of American Engineering Company

Figure 13–2.—Hydraulic telemotor control: (A) telemotor components.

arrows show the flow of hydraulic fluid for right rudder.

Air cocks and filling or charging connections are provided on the receiver cylinders for venting, filling, or purging the hydraulic system.

FILLING THE TELEMOTOR SYSTEM from the charging tank is done by opening the air cocks at the forward telemotor and starting the charging pump. After the oil has appeared at the air cocks, the pumping is continued until the oil is free of bubbles. The air cocks are then closed and the oil allowed to fill the replenishing tank. While the pump is still operating, the valve leading to



Courtesy of American Engineering Company

Figure 13–2.—Hydraulic telemotor control: (B) hydraulic circuit diagram, and (C) schematic diagram of telemotor components.

the replenishing tank is closed and the system is subjected to a slight pressure.

The effective operation of the telemotor system depends upon the PURGING OF ALL ENTRAINED AIR and the elimination of leaks. Purging the system of air, under normal operating conditions, is done by opening the valve leading from the replenishing tank, and the air cocks at the forward telemotor. Because the replenishing tank is located above the highest point of the telemotor system, the air is forced out of the air cocks by the gravity flow of oil. The cocks are closed when the oil flows smoothly without bubbles.

To detect and eliminate leaks in the system, the valves and joints should be inspected frequently. To correct a leaky piston in the internally-packed telemotor, see that the leathers are in good condition, and that the springs (if used) keep the leather in contact with the inside wall of the telemotor cylinders. To stop leaks in the externally-packed telemotor, tighten the glands just enough to cause the packing to be compressed about the rams, until the leak is stopped.

The HYDRAULIC FLUID CHARACTERISTICS are especially important when the telemotor system is exposed to low ambient temperatures. Under such conditions, a high grade mineral oil having a cold pour point of —24° to —40° F should be used. Where low temperatures are not involved or where special oil with the designated cold pour point cannot be readily obtained, the symbol 2075H oil may be used satisfactorily. The oil should have a low rate of expansion and be sufficiently viscous at 150° F to remain a good hydraulic fluid.

When FILLING THE CHARGING TANK with hydraulic fluid, strain the oil into the tank through a funnel which incorporates a 180 mesh screen or use four to six layers of cheesecloth. This prevents the entry of foreign matter and at the same time prevents the entry of air bubbles into the hydraulic system. Also, the oil should never be allowed to become contaminated with water.

Direct-Current Pilot-Motor Control

The direct-current pilot-motor type of remote control is used with some early electrohydraulic steering gears. It consists of a small reversible direct-current motor, which is connected, through a differential gear, to the control shaft of a variable-stroke pump. The pilot motor is controlled by means of a magnetic control panel located next to the motor, and with a master controller located at the steering wheel. The motor has a magnetic brake which stops and holds the motor when the master controller is returned to the neutral position.

Wire-Rope Control

The wire-rope type of remote control is found in some old destroyers and in some recently built small ships. The steering engine control mechanism is connected to the steering wheel by wire ropes. The system has the disadvantages of requiring long leads involving large friction loads; of the ropes being vulnerable to gunfire above decks; of impairing watertight integrity by passage of the cables through bulkheads and decks; and of requiring a comparatively great amount of time for maintenance.

As for CARE OF THE ROPES, the transmission or wheel ropes (as the case may be) should be withdrawn and carefully inspected every six months. If in good condition, they should be well covered with Albany grease and graphite and replaced. If there is any evidence of stranding, the affected part must be repaired or a new rope reeved. When a new rope is to be reeved, care must be taken that the stretch is taken up; otherwise the rope may foul or leave the drums or sheaves. All keys in the transmission shafting must also be inspected to see that they are tight and properly seated.

Gyro-Repeater Compass Control

A gyro-repeater compass control may be used to produce gyro-pilot or automatic steering control, as a supple-

ment for any of the controls described. This equipment, however, is not generally used on combat ships.

ELECTROHYDRAULIC STEERING GEAR

Most steering gear installations on modern naval vessels are of the electrohydraulic type and use only the "A" end of the previously described electrohydraulic speed gear. The development of this type was prompted primarily by the large momentary electrical power requirements for electromechanical steering gears—particularly for vessels of large displacement and high speed, with attendant increased rudder torques. Further advantages of the electrohydraulic steering gear are:

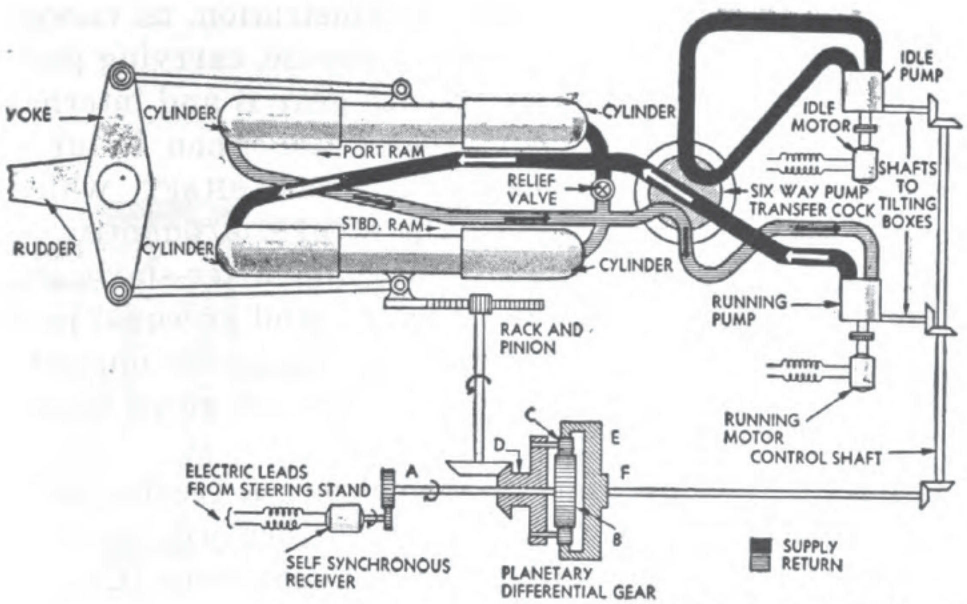
1. Little friction and inertia of moving parts, such as in heavy differential screw and gears.
2. Low power consumption peaks.
3. Sensitive response, with little lag, to movements of the steering wheel.
4. Small deck space and head room required.
5. Savings in weight.
6. Flexibility in the arrangement of hydraulic cylinders, pumps, and control mechanisms.
7. Dependability.

Types of Steering Gears

There are various types of electrohydraulic steering gear layouts in use, but their operating principles are about the same. Some ships have double hydraulic rams and cylinders mounted fore and aft; others have double-cylinder single rams mounted athwartships. Some systems use axial piston variable-stroke pumps; others use radial piston pumps.

How the Steering Gear Operates

Figure 13–3 shows a simple diagrammatic arrangement of a double-ram type electrohydraulic steering gear. Here you see that the RUDDER YOKE is connected to two hydraulic PLUNGERS or RAMS, each of which is equipped with



Courtesy of U. S. Naval Institute

Figure 13–3.—Simple diagrammatic arrangement of a double-ram electro-hydraulic steering gear (with axial piston pumps).

CYLINDERS at both ends. The hydraulic fluid is pumped in the closed system by one of the two rotary, positive displacement, VARIABLE-STROKE PUMPS (axial piston, in this case). The rate of fluid delivery is regulated by the angle of the TILTING BOX in the hydraulic pump, which is in turn controlled either electrically or hydraulically from the steering wheel on deck. The CONTROL SHAFT and gearing are indicated in the illustration.

You will note that the forward-port and after-starboard cylinders are interconnected, and that the same is true of the forward-starboard and the after-port cylinders. A double-acting RELIEF VALVE serves to bypass the fluid from the supply (or the discharge) to the return (or the suction) line, thus relieving the piping from excessive strain, in case an unusual resistance to the rudder (caused by wave action or by jamming) results in abnormal oil pressures. The motors run at constant speed.

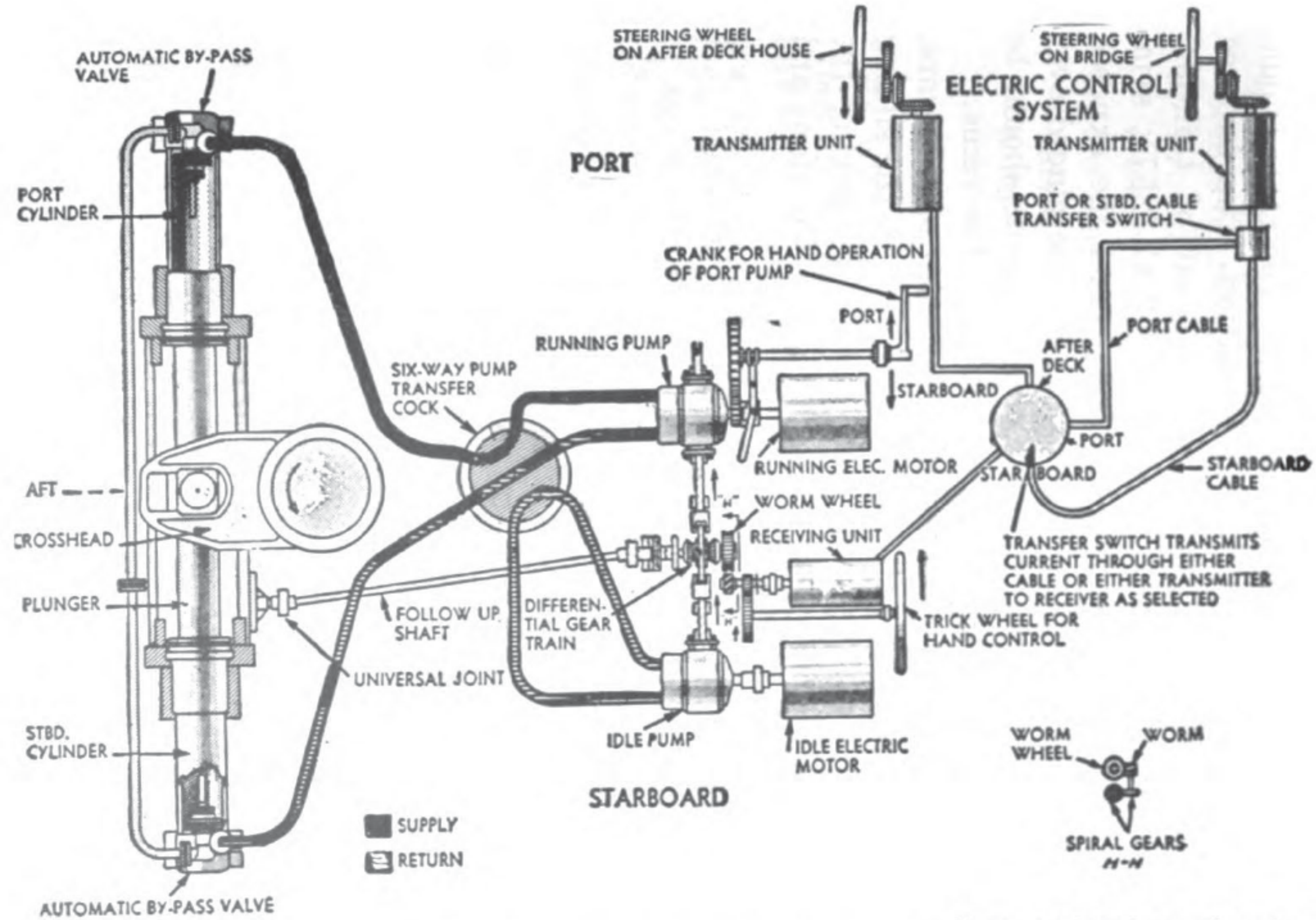
Starting with a neutral position of the tilting box and no flow of oil, suppose the STEERING WHEEL is turned to starboard. The SYNCHRONOUS RECEIVER will then turn cor-

respondingly (counterclockwise in illustration, as viewed from the left). Shaft *A* is turned clockwise, carrying gear *B* with it. The gear C, meshing with gear B and internal gear teeth on E, turns counterclockwise. Then E turns counterclockwise and turns the CONTROL SHAFT, which operates the TILTING BOXES on the PUMPS. A quantity of oil now flows to the forward-port and after-starboard cylinders, the rams move as indicated, and an equal portion of oil is returned to the pumps from the opposite cylinders. The rudder is thereby caused to move to the right.

When the steering wheel and synchronous receiver stop moving, the starboard ram, in moving forward, operates the RACK AND PINION and turns gear *D* clockwise. Gear *B* and shaft *A* are held by the now motionless synchronous receiver, and gears *C* and casing *E* turn clockwise, thus returning the tilting boxes to the neutral position and stopping the flow of oil. The PLANETARY DIFFERENTIAL GEAR, thereby, operates as a follow-up mechanism. If the steering wheel is turned to port, the actions described are the opposite in direction.

In actual installations, two sets of synchronous receivers, two sets of electric motors and pumps, are provided for reliability and flexibility. The SIX-WAY PLUG COCK makes it possible to transfer quickly from the operating pumps to the standby pump.

The single-ram type of electrohydraulic steering gear, illustrated in figure 13–4, operates on the same principle as the double-ram type. The only difference is that there is but one ram, with port and starboard cylinders, mounted athwartships. As the port plunger is forced to move by the pressure of oil against it, the starboard plunger moves correspondingly and forces the same amount of oil out of the starboard cylinder. Note, in figure 13–4, how flexibility of control can be achieved in an electrohydraulic steering system. Detailed descriptions of the steering gear on your ship can be found in the applicable manufacturer's instruction book.



Courtesy of U. S. Naval Institute

Figure 13–4.—Diagrammatic arrangement of a single-ram electrohydraulic steering gear.

Care of Hydraulic Rams

Since portions of the rams are exposed where they fit into the cylinders, it is important that the exposed parts be protected against water, damage from rolling or falling objects, and even from being walked on. The rams should be inspected frequently during operation. The exposed parts should be kept covered with a coat of thin-film rust-preventive compound (Stock No. 52–C–3257), symbol 4065 oil, or other heavy oil. To protect the exposed parts from rolling objects, a guard should be placed over the parts, and the steering gear compartment should be kept clear of loose gear that may slide into the rams.

If rust accumulates on the rams in spite of this care, it should be removed with a wire brush—with the sliding parts of the rams covered with clean rags during the process, since pieces of wire might stick to the rams and be pulled into the cylinders.

The PACKING FOLLOWERS should be tightened just enough to maintain sufficient pressure on the rings to prevent leakage. A special spanner wrench is provided for turning the follower, but in tightening the follower be careful not to apply excessive pressure, which would result in rapid wear and improper functioning of the packing.

The oil in the high-pressure hydraulic system should be filtered about every six months. This prevents the accumulation of dirt and other foreign matter, which may injure the rams and variable-stroke pumps. When make-up oil is added to the system, the oil should be filtered through cheesecloth.

If no LUBRICATING INSTRUCTIONS are provided with the installation, a set of instructions should be prepared and posted on the bulkhead of the compartment.

Inspection

The following steps should be taken in connection with the inspection and care of electrohydraulic steering gears:

1. Check piping periodically for leaks.
2. Check oil level and condition of oil in expansion tank.
3. Filter oil in the high-pressure system periodically.
4. Inspect steering gear thoroughly before putting it into operation.
5. Protect exposed parts of the rams from water, dirt, loose objects, etc.
6. Do NOT attempt to test the high-pressure relief valve; this is a job for experienced shipyard personnel only.

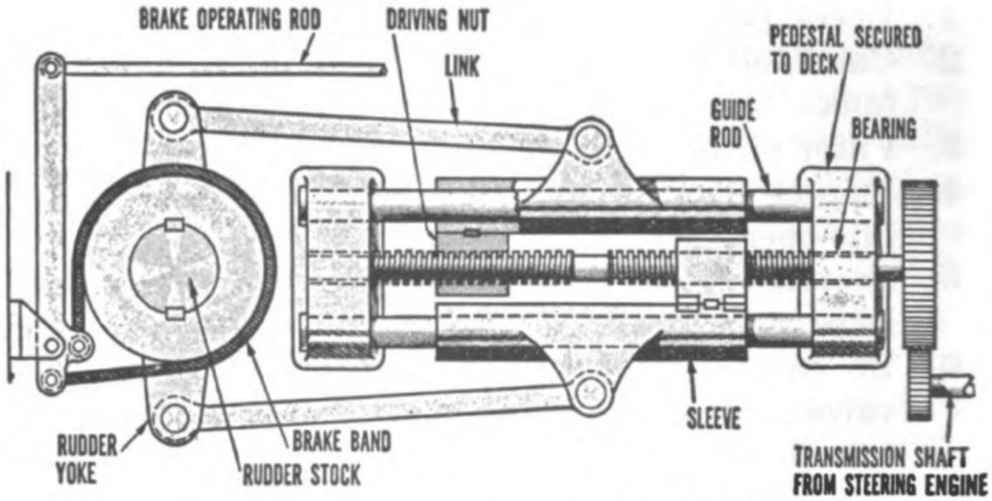
STEAM-DRIVEN STEERING GEAR

As with the electrohydraulic gears, there are many types of steam steering engines, but all of them operate on the same general principle. You should understand this general principle, as well as what inspections must be made, and how to maintain the mechanism in good working order.

Principles of Operation

Two or more cylinders are used on this steering gear, each acting as a simple reciprocating steam engine, but driving a common crankshaft. The cranks are placed at right angles when two cylinders are used, to provide for a continuous, even torque, and to keep the engine from ever being at a dead-center position. To reduce the height of the installation, the cylinders are sometimes placed in a horizontal or inclined position.

Figure 13–5 illustrates how the crankshaft may be arranged to turn the rudder through a right-and-left screw steering gear. Or the turning may be through a gear train comprised of a worm gear on the crankshaft, which drives a wheel equipped with a spur pinion, which in turn drives a gear quadrant keyed to the stock of the rudder. Except for certain auxiliary ships, steam drives have been abandoned because of vulnerability of the steam piping, stray heat, poor economy, excessive space and weight, and lack



Courtesy of U. S. Naval Institute

Figure 13–5.—Right-and-left screw steering gear.

of flexibility. Tugs, mine-sweepers, etc., however, may be equipped with steam steering gears (worm gear and quadrant).

Inspection and Care

All bearings in the transmission gear of the steering engine must be well lubricated. Bearings that are difficult to reach or those located in hot places should be given special attention. The oiling arrangements (physical arrangement of the gears) of the FLOATING RING should be examined frequently and supplied with the specified lubrication.

The floating ring in the steering stand, or the roller bearing fitted for carrying the weight of the vertical shaft, MUST BE KEPT PROPERLY ADJUSTED, so that the weight will not be taken on the lower bearings.

Emery, emery cloth, or any other gritty substance should never be used for cleaning the bright surface of the steering engine or its gear. The spaces adjacent to gears must be kept clean, and not used as storage places for clothing or other articles. Such material might become entangled with the transmission gears.

WHEN NOT UNDER WAY, and the steering gear is not

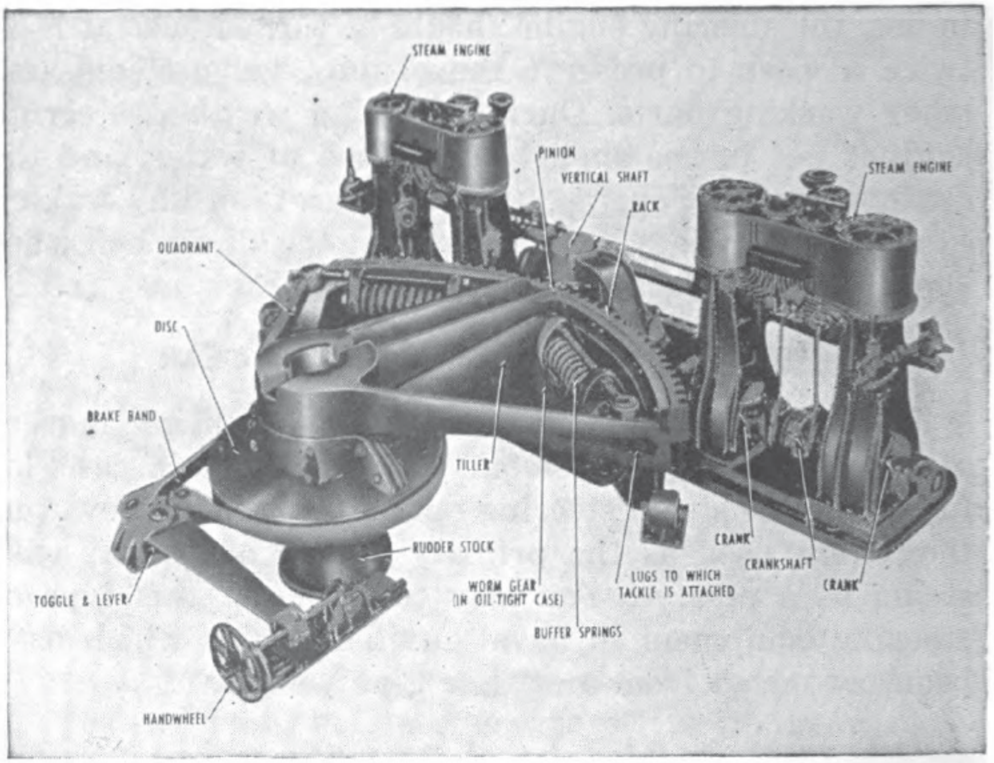
in use, the steering engine should be turned over at least twice a week to preserve the pistons, valve stems, and other working parts. During freezing weather, steering engines not in use should be drained of water, and the drain valves left open so that condensate of any leaking exhaust steam may drain. Be sure the drain holes are kept clear; otherwise, the cylinders or jackets may freeze.

ELECTROMECHANICAL STEERING GEAR

Electric motors were first introduced as prime movers of steering gears on combat ships to serve in cases of failure of the steam steering engines. Later on, however, they were used as the primary source of power, with steam as a reserve. You may come across this type of steering equipment in naval auxiliary ships which have been converted from maritime type vessels.

Principles of Operation

The principles of operation are practically the same in all steering gears of this type. Any differences that exist are mainly in the manner in which the driving motor is connected to the tiller, and the method by which the motor is controlled. The electric motor drives a right-and-left screw (fig. 13–5), or worm gears and quadrant (13–6), as with the steam-driven gears. The motor, however, is placed far aft and thus does not require a long connecting shaft, as does steam type. In the gear and quadrant type, the steering engine is located in the steering compartment. However, in the wire-rope and drum type, it is generally in a machinery space as close as possible to the pilot house in order to keep length of control shafting to a minimum and thereby reduce lost motion. When the control switch is moved to a neutral position, a dynamic braking action slows down the motor armature, held by magnetic brakes. One disadvantage of the electromechanical gear is the excessive power required to start, accelerate, and bring to a stop the motor and screw gear.



Courtesy of Cornell Maritime Press

Figure 13–6.—Worm gear and quadrant-type steering gear.

STEERING ENGINEROOM WATCH

During your watch in the steering engineroom make sure that standby equipment is in momentary readiness in case of an emergency. Inspect the steering gear thoroughly. Check to determine that the trick wheel(s) are in the declutched position(s). Feel the various parts of the unit in operation. Any part that is too hot to the bare hand should be reported immediately to the Officer of the Deck on the bridge and the Officer of the Watch in the main engineroom. Investigate for possible binding, overloading, or lack of lubrication. Listen for new or unusual sounds which indicate loose parts or wear. Check and determine that there is sufficient hydraulic fluid in the tanks and that there are no leaks in any of the lines or fittings. Piping leaks are unusual but could occur following unusual strain (rough seas) on the ship's hull. Such leaks may be eliminated by tightening the flange

bolts. Be sure to bleed all air out of the systems. Slow leaks at the packing glands of the rams are not objectionable since the small flow of hydraulic fluid provides lubrication. However, be sure to keep oil off the deck. While doing any work on the steering gear, keep the hydraulic fluid and all parts exposed to the oil clean and free of foreign matter. Check and determine that all housings, grease fittings, and surfaces to be lubricated are properly filled or lubricated in accordance with instructions on the lubrication chart.

When working in the steering engineroom be extra careful. The space is not too roomy and you are apt to become careless. Be especially careful of your hands when working in the confined spaces around the rams and actuating gears. All clothing should be free from loose ends.

STEERING CASUALTY

Steering is normally controlled in the pilot house by the helmsman, who receives his orders from the Commanding Officer via the Officer of the Deck. If steering control is lost from the pilot house, control must be shifted to steering aft as an emergency measure. Shifting of control may be necessitated by damage to the telemotor system or remote control apparatus, or as a routine under way training measure to test the preparedness and efficiency of the steering engineroom watch party.

In general, this is what would take place when shifting from normal steering control to steering aft in event of a steering casualty. The pilot house watch would sound the steering alarm located in steering aft. At the same moment "STEERING CASUALTY—STEERING CASUALTY" would be sounded over the general announcing system and the JV circuit. The steering engineroom watch party would immediately, and without further orders, take control on the trick wheel. They would match the trick wheel to the actual rudder position. If necessary, the steering engineroom watch party would shift to the standby unit.

They would report to the Officer of the Deck as soon as steering aft had steering control and would steer as directed by the Officer of the Deck. You, the Machinist's Mate, would determine the nature and extent of damage or casualty, and report to the Officer of the Deck and the Officer of the Watch in the main engineroom. As soon as you have repaired the casualty, you report it to the Officer of the Deck and the Officer of the Watch in the main engineroom. Upon being ordered to shift back to the pilot house, you would bring the rudder amidships with the trick wheel, shift control to the pilot house, and report to the Officer of the Deck that the pilot house has control.

ANCHOR WINDLASSES

The term WINDLASS refers to a piece of deck machinery used primarily for paying out and heaving in an anchor chain. A WILDCAT (drum) may be mounted vertically or horizontally at the end of the windlass shaft for handling the anchor chain. The wildcat is usually fitted with WHELPS to engage the anchor chain. On the windlass there may also be a *capstan head* or *warping head* (concave drum) for handling lines.

General requirements of the anchor windlass are that it must be simple, rugged, reliable, capable of reversal, and have a high mechanical advantage, suitable brakes, and a control for veering the chain. Three general types of power-driven anchor windlasses are used; electrohydraulic, electric, and steam. Hand-operated windlasses are limited to small ships where the weight of the anchor gear is such that it may be handled in a reasonable time and without excessive effort on the part of operating personnel.

Electrohydraulic Windlasses

Electrohydraulic anchor windlasses are advantageous where the load varies over a great range because of the amount of chain cable out, strength of the wind, strength of the tide, and imbedment of anchor on the bottom.

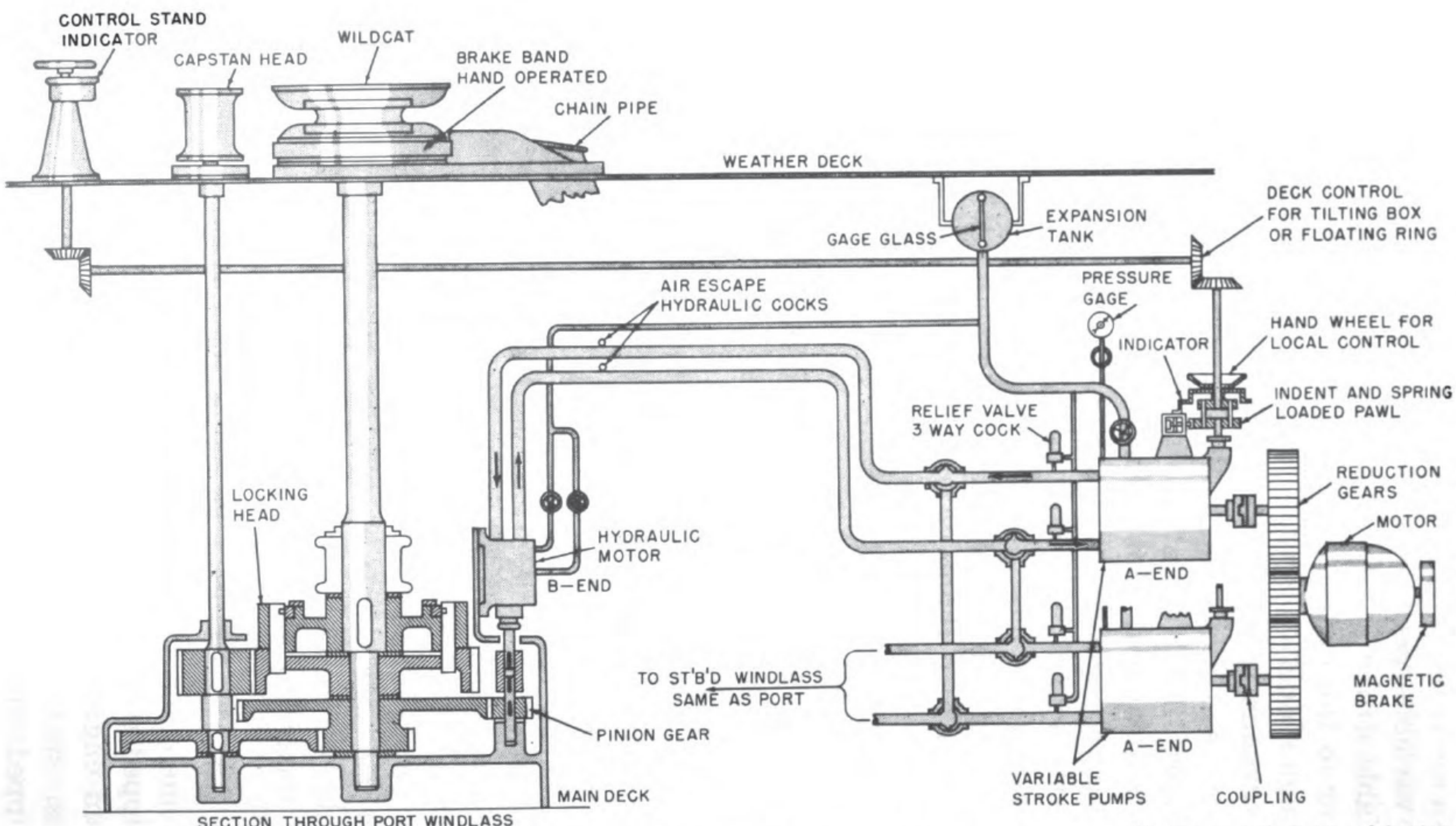
An electric motor drives the hydraulic pump, A-end of the variable-speed gear (rotary, positive displacement, variable-stroke pump). Oil under pressure transmits the power to the hydraulic motor, B-end of the gear which, through reduction gearing, rotates the windlass. The rate of hydraulic power delivery may be regulated by varying the stroke of the A-end of the pump.

Figure 13–7 illustrates a typical electrohydraulic windlass arrangement. This particular mechanism has but one constant speed electric motor, which drives the two variable-stroke pumps through a coupling and reduction gear. Other installations include two motors, one for driving each of the pumps. Each pump normally drives one particular wildcat, though (with the use of 3-way plug cock type valves) either pump may drive either of the two wildcats. The hydraulic motors drive the wildcat shafts by means of multiple spur gearing and a locking head. The locking head permits disconnecting of the wildcat shaft thus permitting free operation of the wildcat as when dropping anchor.

Each windlass pump is controlled either from the weather deck or locally with handwheels on shafting leading to the pump control. An indent and spring-loaded pawl is installed in the shaft for centering and holding the control in neutral. Replenishing pipes from each A-end and B-end of the casing lead to an expansion tank overhead. The hydraulic system will require your attention. Be sure that the hydraulic system is always serviced with the specified type of clean oil. All control shafts should be lubricated with the correct lubricant. Information regarding the pumps will be found in chapter 8.

Electric and Steam Windlasses

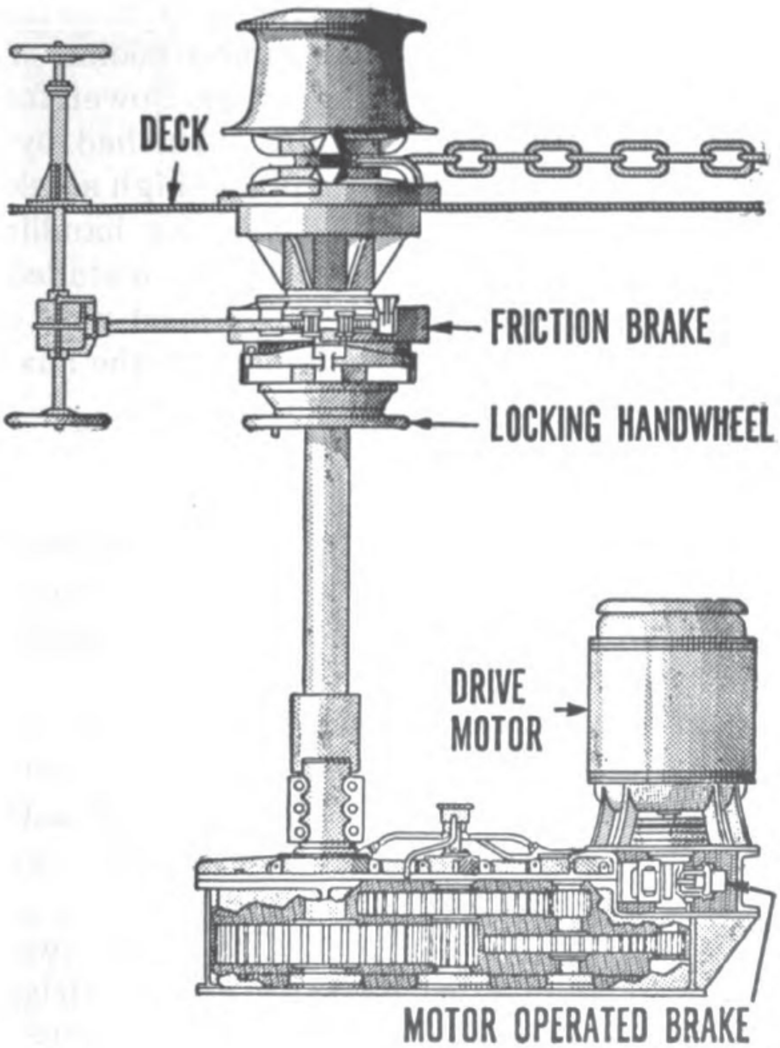
Some older naval ships (battleships and cruisers) are equipped with geared windlasses driven by reciprocating steam engines or electric motors; also, some new light ships, such as destroyers and destroyer escorts, are equipped with the electric motor variety. The motor or



Courtesy of U. S. Naval Institute

Figure 13–7.—Typical electrohydraulic anchor windlass arrangement.

steam engine drives a worm gear which is meshed with a wheel on the windlass shaft. Some types of mechanisms are spur geared. Band brakes are provided at the wild-cats on the upper deck, and clutches are provided at the



Courtesy of U. S. Naval Institute

Figure 13–8.—Typical electromechanical-type anchor windlass.

lower end of the vertical shaft. Worm gears are equipped with thrust bearings to absorb the thrust at both ends when hoisting and lowering are being performed. Figure 13–8 illustrates an electric spur-gear type windlass of a modern destroyer.

WINCHES AND CAPSTANS

A winch is a piece of deck machinery that has a large winding drum on a horizontal shaft for handling heavy loads with wire rope. In addition, cargo winches may be equipped with one or two gypsy heads fitted for handling manila. Winches are used for heaving in on mooring lines, hoisting boats, topping lifts on jumbo booms of large auxiliary ships, and for handling cargo. Power for operating shipboard winches is usually furnished by steam or electricity. Where delicate control and high acceleration without jerking are required, such as for handling aircraft, electrohydraulic winches are usually installed. Some of the modern auxiliary ships are equipped with electrohydraulic winches, while the remainder of the auxiliaries are equipped with steam-operated winches.

Cargo Winches

Among the various types of winches for general cargo handling are: double-drum double-gypsy, and single-drum single-gypsy units. Four drum, two gypsy machines are generally used for mine sweeping.

The steam-operated deck winch (figure 13–9) is driven by a two cylinder, single expansion, double acting reciprocating engine. The drive is by means of a train of spur gears in which a gear shift is provided to give two drive speeds.

Illustrated in figure 13–9 is a winch with two gypsy heads ①, one mounted at each end of the main drive shaft. The speed and direction of rotation of the engine is controlled by a hand lever ⑭. With the winch in "compound gear" the drum turns to lift a load when the hand lever ⑭ is raised. With the lever in this position, a spool-type valve passes steam from the reverse valve ⑨ through the two top horizontal pipe lines ⑤ to the cylinders where it drives the engine. The two lower pipes ④ are exhaust lines. When the lever is lowered below the horizontal position, the direction of steam flow is reversed

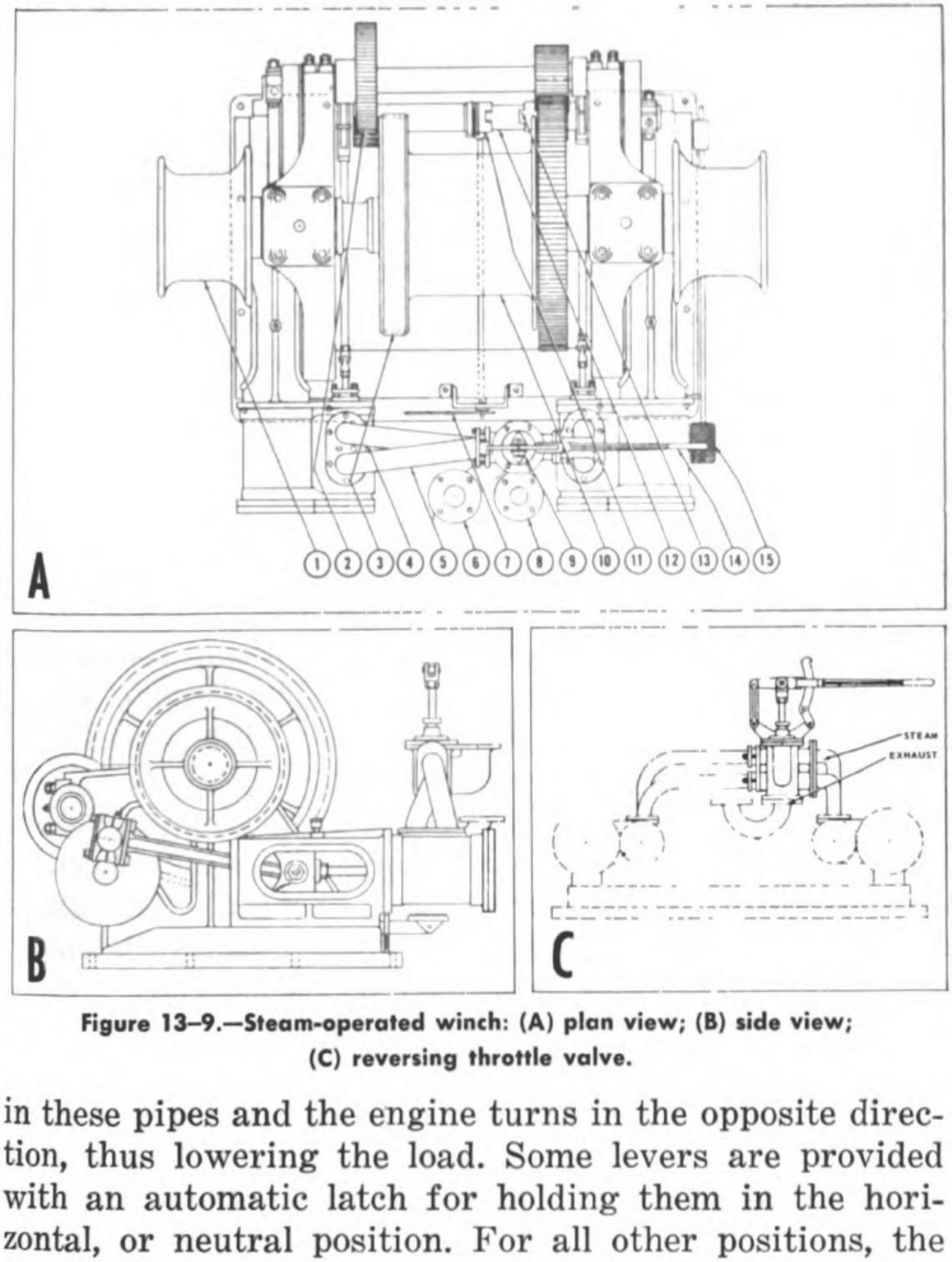


Figure 13–9.—Steam-operated winch: (A) plan view; (B) side view; (C) reversing throttle valve.

in these pipes and the engine turns in the opposite direction, thus lowering the load. Some levers are provided with an automatic latch for holding them in the horizontal, or neutral position. For all other positions, the controls must be in the hands of the winch operator who must hold the lever in position for the desired speed.

A spool-type steam valve (not shown in figure 13–9) slides back and forth, opening and closing the ports for the flow of steam to or from the cylinders. The reciprocating motion of the steam valve is imparted to it by a rod moving through a stuffing box and connected to the eccentric on the main shaft.

With the winch in "single gear" the direction of rotation is reversed and a load is raised by lowering the lever. The clutch mechanism consists of a sleeve ⑪ which is keyed to the crankshaft ⑫ and provided with a shifter yoke which is operated by a lever ⑦ located near the reverse valve ⑨. When this lever is thrown to the left, the position shown in figure 13–9A, the pinion which is integral with it, is engaged with the gear ② on the intermediate shaft. This is the "compound gear" position and gives a slower drum speed with an increase in available line pull. When the shifter lever ⑦ is thrown to the right, the driving sleeve is shifted to the right. This disengages the pinion from the intermediate shaft gear ② and engages the square jaw clutch ⑬ and pinion which is always in mesh with the main drive gear. This gives a direct drive from the crankshaft to the main shaft, and is called the "single gear" position. The "single gear" gives a higher drum speed for a given engine speed, but with a decrease in the available line pull.

The "neutral" position is obtained by placing the shifter lever ⑦ in the vertical position, leaving no connection between the driving sleeve ⑪ and the pinion at either end. The shifter lever is provided with a means of latching it in any of the three described positions. Care should be taken to latch the lever in the desired position before the winch is operated.

When the winch is under heavy load, there is a high pressure between clutch faces, or gear teeth. This makes it impossible to shift the sleeve and change the gear ratio. To make a change, it is necessary to remove the load from the winch and then turn the engine over very slowly while making the shift.

With the engine running in a given direction, the shifting from "compound gear" to "single gear," or vice versa, reverses the direction of drum rotation. The design of the winch is such that lowering the load by lowering the hand lever ⑭, applies for heavy loads (compound gear), while the reverse, lowering the load by raising the lever

(single gear) applies for higher speeds where heavy loads are not encountered.

The winch is provided with a gypsy head ① at each end of the main drive shaft. Being keyed to the shaft, the gypsies are turned with the hoisting drum. The drum ⑩ is provided with a standard type of band brake ③ with a foot-operated control and ratchet lock. The locking device is controlled by springing the foot pedal ⑮ laterally. The brake band is secured to the winch bed plate in such a manner that the brakes may be conveniently taken up to compensate for wear.

Maintenance of Steam Winches

Before ordering steam from the engineroom for deck winch operations, the machinery should be thoroughly lubricated and the drum clutches disengaged. All drain cocks should be opened before the steam valve is "cracked." The engine should be idled slowly until all water is removed and the engine is properly warmed up. Run the winch back and forth until all water is driven from the cylinders and clouds of steam rise from the drain cocks. Close the drain cocks and the deck winch is ready for operations.

While the engine is idling, listen for any rubbing or other unusual noise that might indicate a broken piston ring, a loose piston, or a faulty valve. A loose bearing can seldom be detected before a working load is put on the engine.

The engine should be well lubricated while the winch is in use. Some parts will require hourly lubrication while other parts will require lubrication every four hours. The packing glands should be kept tight. Do not apply excess pressure in tightening the packing glands, as too much pressure will score the piston rod and burn the packing. Lubricating oil should never be put on the brake drum or the brake lining.

If the brake fails to hold the weight for which the winch

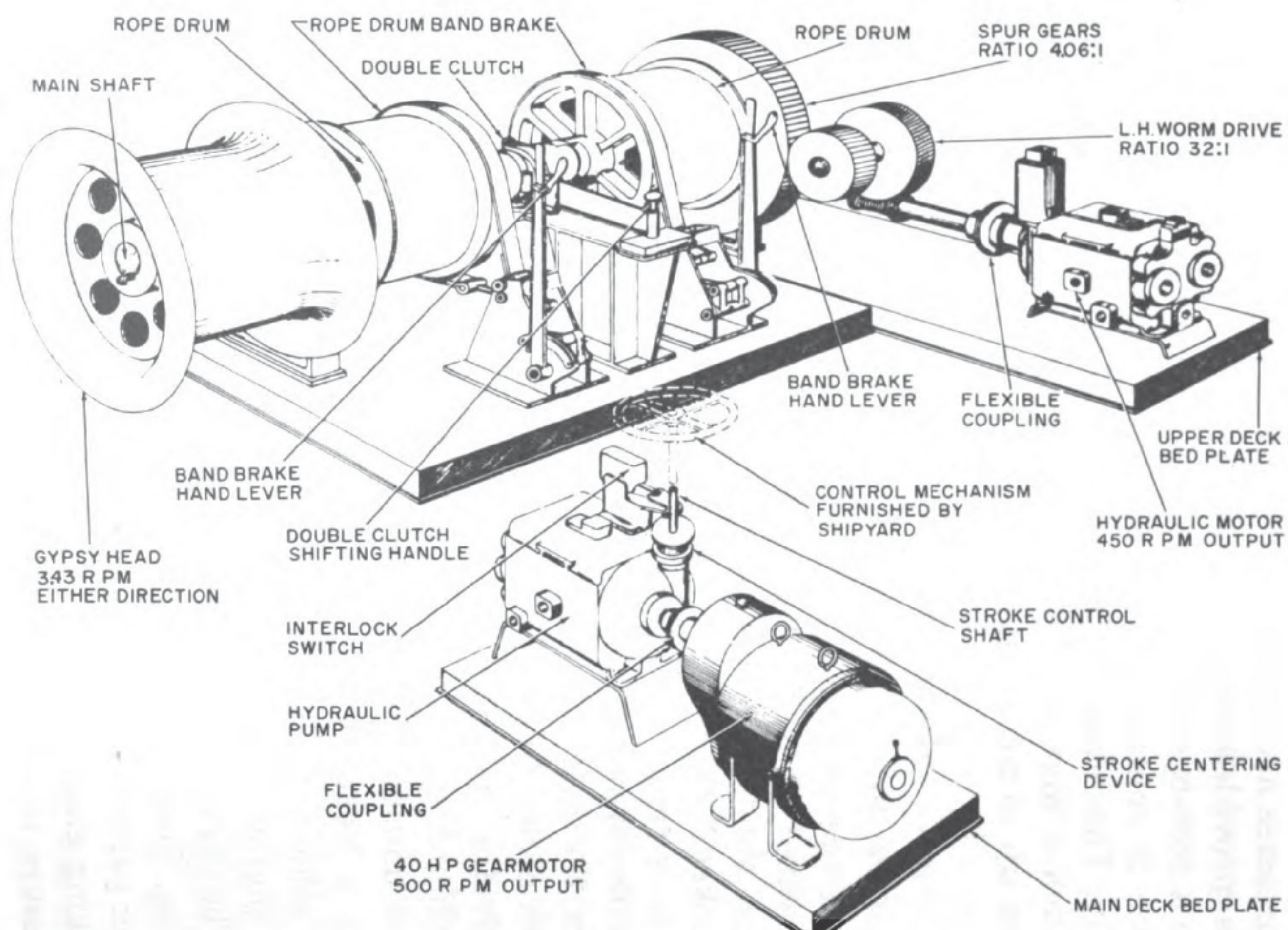


Figure 13–10.—Electrohydraulic winch units.

was designed, adjust the brake. If the brake lining is so worn that the rivets come in contact with the brake drum, the lining should be renewed.

For information regarding points to lubricate and the correct amount of lubrication to be used, check the manufacturer's instruction book for the particular winch aboard your ship.

Electrohydraulic Winches

These winches (fig. 13–10) are of the horizontal electrohydraulic type consisting of an upper deck assembly hydraulically connected to a main deck power plant located below. The upper deck assembly consists essentially of a gypsy head and two wire rope drums mounted on a common shaft and driven through a gear reduction unit by a hydraulic motor. The main deck power plant consists of a hydraulic pump driven through a flexible coupling by a continuously running electric gear motor.

The gypsy head is keyed to the main shaft and rotates whenever the winch is operating. Winding drums are not keyed to the shaft. When the drums are to be used, they are connected to the main shaft by the clutching mechanism.

In most electrohydraulic winches, the hydraulic transmission is of the type pump described previously on page 493 of this chapter. The maximum hydraulic pressure encountered for the 10,000- and 20,000-pound condition is 320 psi, and for the 30,000-pound condition is 485 psi.

Figure 13–11 illustrates schematically the hydraulic piping of an electrohydraulic winch. The diagram shows main shaft rotation and high-pressure oil flow with stroke control shaft rotated in a clockwise direction, as shown by the arrow. Counterclockwise rotation of the stroke control shaft beyond its neutral position directly reverses the above procedure. This causes the main shaft to rotate in a clockwise direction because the direction of high-pressure oil flow has also been reversed.

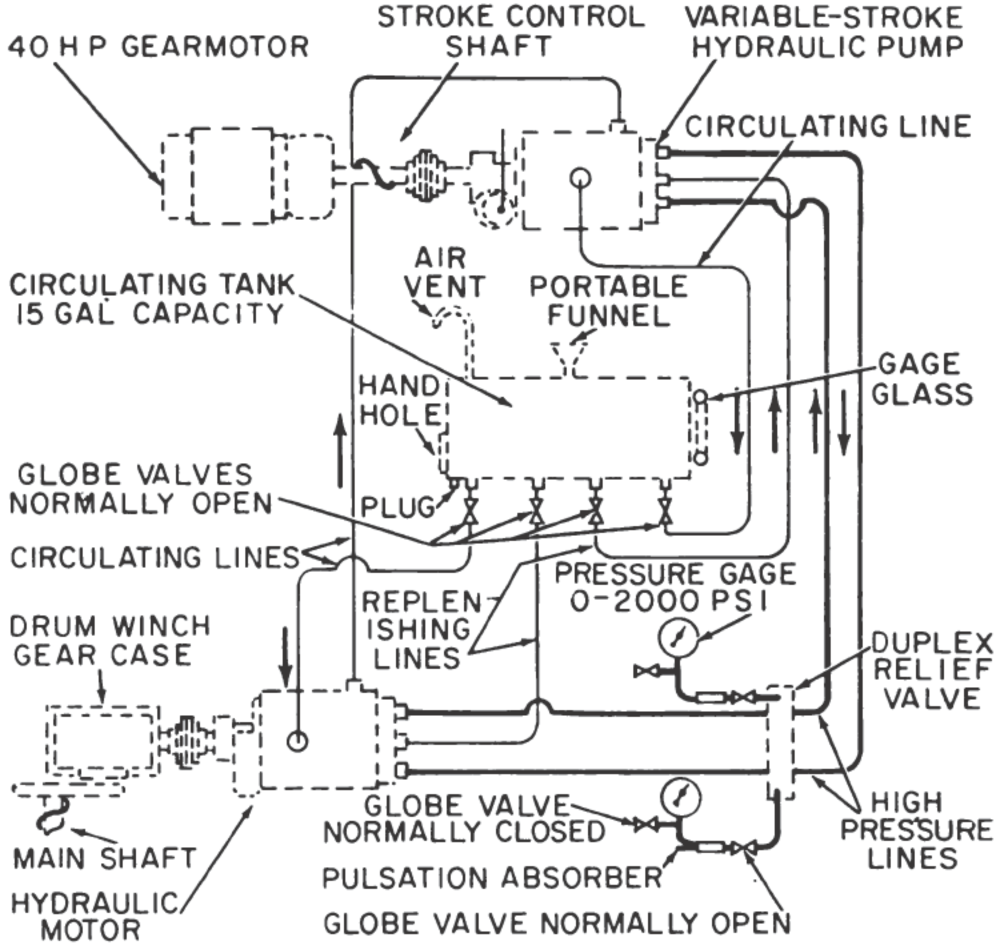


Figure 13–11.—Schematic piping diagram of electrohydraulic winch.

Boat Handling Winches and Davits

Double-gypsy winches without a drum are frequently used for handling boats. Winches are normally powered by electric motors. Some of the older ships may have the winches powered by steam engines, hydraulic transmission systems, or diesel engines. In addition to the winch, there is a set of DAVITS (projecting steel arms). The main purpose of the davits is to swing a boat out from its stowage place to a point from which the boat may be lowered and to perform the reverse of the process when the boat has been hoisted up again. The actual hoisting or lowering is done by means of tackles called BOAT FALLS, which run from the davit heads to the boat's bow and stern. The hauling part of the falls leads from the davit

heads to a belaying point for lowering, or to a mechanical source of power for hoisting in.

There are three types of davits (fig. 13–12) in use: the gravity davit, the quadrantal davit, and the radial davit.

The GRAVITY DAVIT was extensively used during World War II on transports, cargo ships, and landing craft.

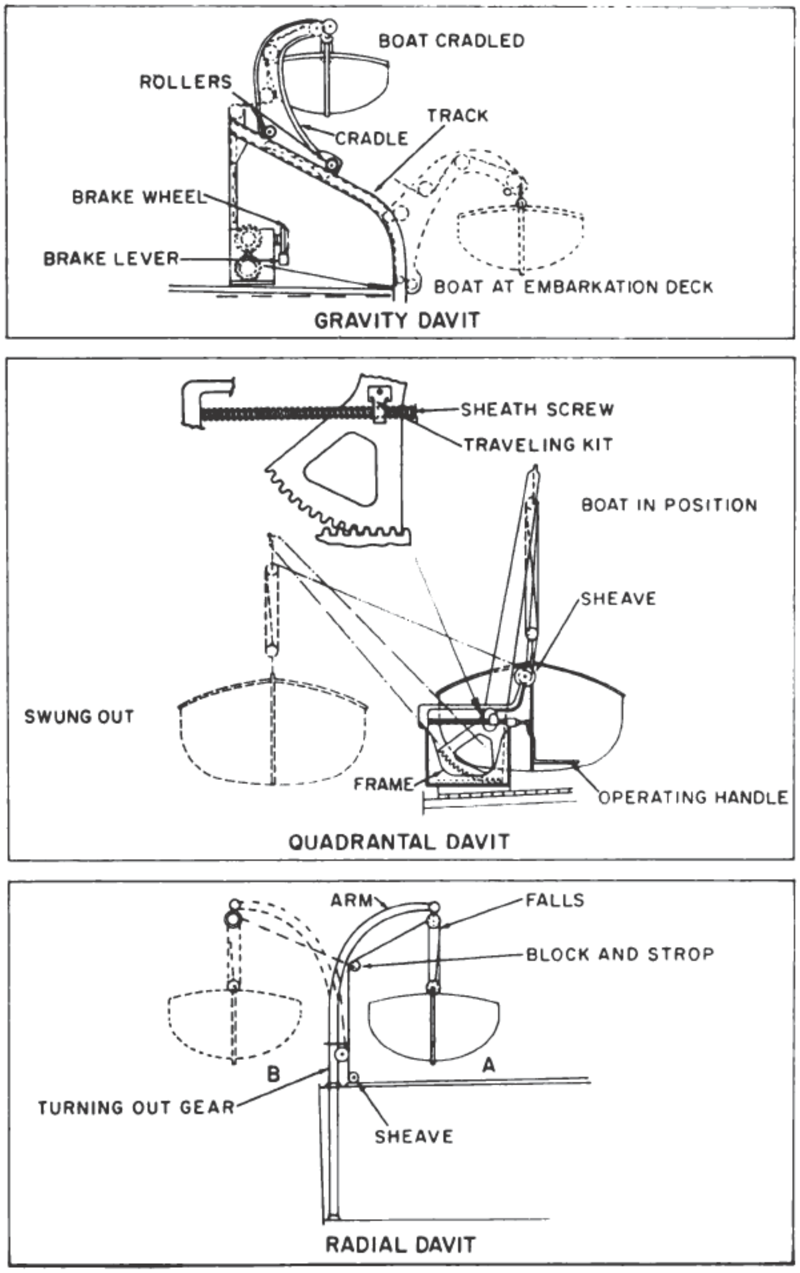


Figure 13–12.—Three types of davits.

In this type of davit, the boat is handled by structural steel arms mounted on rollers on inclined trackways. The lower end of the trackway is curved so that when the arms reach this point, they dip down sufficiently to release the runner block from its hook on the davit head, thus permitting the boat to lower. The operation may be started by releasing the boat gripes and raising the brake lever on the winch; speed is controlled by gradual application of the brake.

The QUADRANTAL DAVIT has been used in all classes of ships, including combatant ships. In this type of davit the arms are racked in and out by means of a sheath screw which may be operated by power or by a hand crank. The boat hoist may be of manila led to the gypsy of a deck winch or wire rope led to the drum of a special boat winch furnished with the davits.

The oldest type of davit is the RADIAL DAVIT. To swing out a boat with radial davits, the boat must first be lifted off the chocks on which it rests when secured for sea. The boat must then be moved aft until its bow will clear the forward davit. Next, that davit is rotated outboard, and the boat's bow is pushed outboard. The after davit is also rotated outboard, so that the stern, too, goes over the side; and the boat is then ready to lower away. Radial davits provide a quick means for swinging out a comparatively light boat.

Capstan

A capstan is a spool-shaped vertical, revolving drum for heaving in on heavy mooring lines. Figure 13–13 shows a vertical-shaft anchor windlass capstan head. The capstan head is a component part of the anchor windlass as shown in figure 13–8 and 13–13, which happens to be topside equipment on a destroyer. Capstans that are not component parts of anchor windlasses are usually electrically or steam powered. The chief difference between a gypsy head and a capstan head is the fact that the former

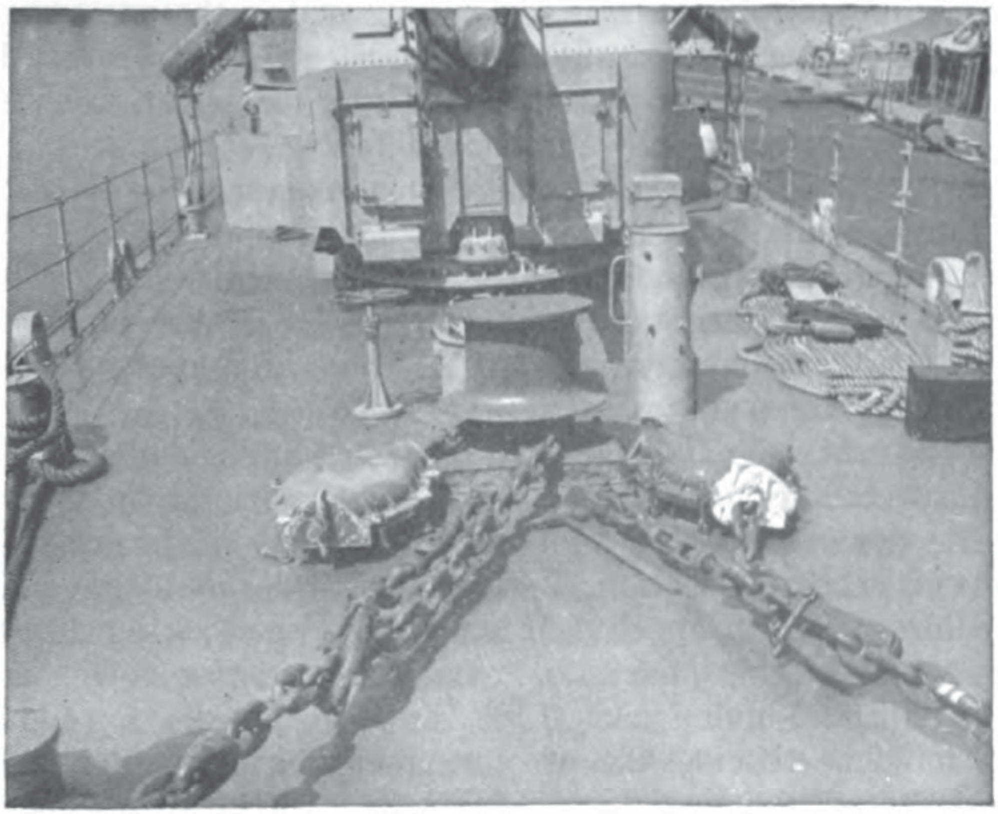


Figure 13–13.—Vertical-shaft anchor windlass capstan head.

has a horizontal shaft and the latter a vertical shaft. Consequently, a capstan is always free of the fair-lead problem which is often present on a gypsy. A line leads fair to a capstan from any horizontal direction.

General Winch Maintenance

Steam engines used for driving winches are generally reversible, either by a reversing throttle valve or by a link mechanism. They have balanced piston valves, instead of plain D-type valves. The rated capacity of the unit is generally based on a steam pressure of 125 psi, controlled by pressure regulators in the steam line.

All drain valves should be left open in cold weather when the engine is not in use, and the engine should be warmed up and started with drain cocks open before being subjected to a load. Frequent warming-up and turning-over should be done during cold weather. Hy-

draulic pumps and lines are maintained in the same way as for any other hydraulic system. Electric motors should be kept free from moisture and any electrical troubles should be handled by the Electrician's Mates.

Where band brakes are used on the drums, the friction linings should be inspected regularly, and renewed as necessary. Care should be taken to prevent oil or grease from accumulating on the brake drums. Brake-operating mechanisms, latches, and pawls should be inspected periodically for proper functioning.

Winch drums driven by friction clutches should be inspected frequently to ensure that the friction material has not deteriorated and that grease and oil do not prevent proper operation. Positive clutches should have all sliding parts properly lubricated, and the locking device on the shifting gear should be inspected to ensure that it will hold under load. Oil levels of gear reduction units should be checked for amount, temperature, and purity of the oil. Pressure grease lubrication fittings (normally provided on slow-moving parts) should be inspected at regular intervals.

CRANES

A CRANE is a machine in which a load is handled from a boom, jib, or an overhead bridge. Cranes are designed for raising a load, lowering it, and moving it in horizontal directions. You will find cranes installed on carriers, battleships, cruisers, and auxiliaries. Cranes are used for handling airplanes, boats, bombs, torpedoes, mines, missiles, trucks, paravanes, and stores.

Construction of a Crane

Cranes in general include the boom, king post, king post bearings, sheaves, hook and rope, machinery platforms, rotating gear, drums, and hoisting, topping and rotating drives.

The HOISTING WHIP and TOPPING LIFT of a crane are driven by hydraulic variable speed gears, through gearing

of various types. This provides the wide range of speeds and delicate control required for airplane handling. The crane is rotated by an electric motor connected to worm and spur gearing or by an electric motor and hydraulic variable-speed gear connected to appropriate reduction gearing.

Some of the airplane electrohydraulic cranes are also provided with automatic slack line take-up equipment, consisting of an electric torque motor geared to the drum. This torque motor assists the hydraulic motor drive to reel in the cable in case the plane is lifted faster by the water than it is being hoisted by the winch. Some airplane cranes are also equipped with a hydraulically operated booster system to assist the operator in turning the hand wheel more rapidly when hoisting a plane from the water.

In some ships, the cranes may be driven by electric motors, diesel engines, or by hand.

Electrohydraulic equipment for the cranes consists of one or more electric motors, running at constant speed. Each motor drives one or more A-end variable displacement hydraulic pumps whose strokes are controlled through operating hand wheels. START, STOP, AND EMERGENCY RUN push buttons are located at the operator's station to the operating hand wheels for the control of the electric motors (fig. 13–14). Interlocks are provided to prevent starting the electric motors when the hydraulic pumps are on stroke. B-end hydraulic motors are connected to the A-end pumps by piping, and drive the drums of the hoisting and topping units or the rotating machinery. The working hydraulic pressure for cranes is approximately 760 psi.

Reduction gears are provided between the electric motor and the A-end pump, between the B end hydraulic motor and the drum, and between the B end hydraulic motor and the rotating pinion. Each hoisting, topping, and rotating drive is provided with an electric brake on the hydraulic motor output shaft. The electric brake is so interlocked with the hydraulic pump control that the

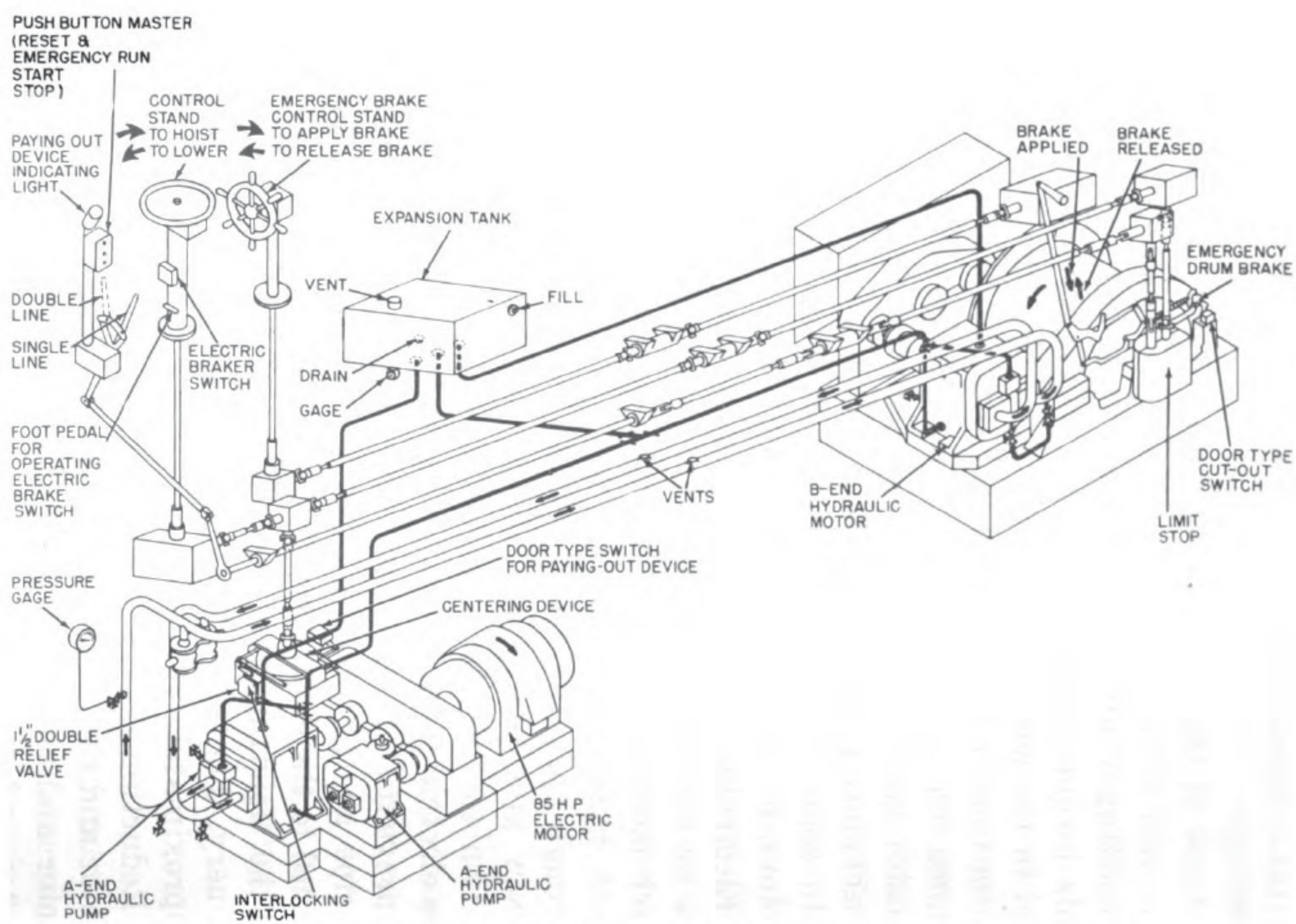


Figure 13–14.—Schematic diagram for boat and airplane electrohydraulic cranes.

brake will set when the hydraulic control is on neutral or upon loss of electric power. A centering device is provided for accurately finding and retaining the neutral position of the hydraulic pump.

Relief valves are installed for protection of the hydraulic system. These relief valves are set at 150 percent of the normal working pressure.

Rapid Slack Take-up Device

The rapid slack take-up device consists of an electric torque motor which is connected to the airplane hoist drum through reduction gearing. This device works in conjunction with the pressure stroke control on the hydraulic pump, and provides for fast acceleration of the hook in the hoisting direction under light hook conditions. Thus, slack is prevented from forming in the cable when hoisting is started or if a wave suddenly accelerates the airplane to a much greater speed than it is being hoisted by the crane.

Light Hook Pay-out Device

A light hook paying-out device (fig. 13–15) is usually installed on any crane that has only one whip. This device is mounted on the end of the boom for paying out the hoisting cable when the weight of the hook and cable beyond the boom head sheave is insufficient to overhaul the cable as fast as it is unreeled from the hoisting drum.

When the mechanical hoist control is in neutral, the torque motor is not energized and the cable is gripped lightly by the action of a spring. Moving the hoist control to "lower" energizes the torque motor, and the grip sheaves clamp and pay out the cable firmly as it is unreeled from the hoist drum. When the hoist control is moved to "raise," the torque motor is reversed and operates to unclamp the grip sheaves. A limit switch opens and automatically deenergizes the paying-out device. Figure 13–15 shows the light hook condition with the torque motor paying out the cable. The dotted arrows indicate

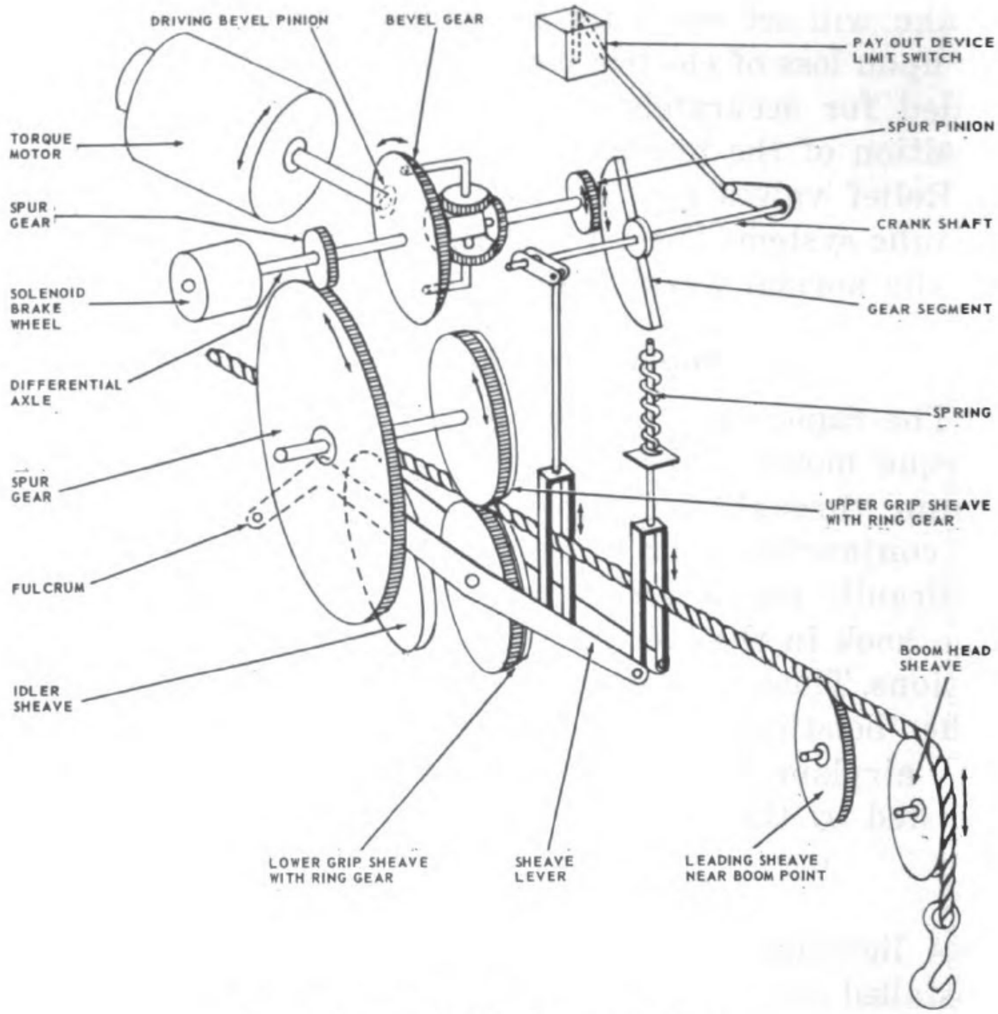


Figure 13–15.—Light hook pay-out device.

the direction in which the parts of the mechanism tend to turn.

Maintenance of Cranes

Inspect the machinery for the cranes installed on your ship and acquaint yourself with the mechanisms involved. Keep oil levels in replenishing tanks of electrohydraulic systems at the prescribed levels, and keep the systems clean and free of air. The oil used should be as specified by the manufacturer. Ensure proper lubrication and meshing of rotating gear and pinion. Check regularly the limit stop operation for extreme positions of travel and other installed mechanical safety devices. When not in

use, the crane should be secured in its stowed position and all electric power to the crane controllers should be disconnected at the distribution panel by the Electrician's Mates. The manufacturer's instruction book should be consulted whenever maintenance problems with which you are unfamiliar arise.

ELEVATORS

All carriers are provided with two or more inboard elevators which are capable of handling airplanes between the flight and hangar decks at relatively high speed. Shipboard elevators may be divided into two distinct classes: ELECTROHYDRAULIC and ELECTROMECHANICAL ELEVATORS. The ELECTRO-HYDRAULIC ELEVATORS may be divided into two general types: the DIRECT PLUNGER LIFT and the PLUNGER-ACTUATED CABLE LIFT. Freight, bomb, mine, and torpedo elevators are quite similar in design to the electromechanical airplane elevator.

The main airplane elevators on aircraft carriers are capable of making a round trip in 45 seconds with all pumps in use, or a round trip of 53 seconds with two pumps in use; or a round trip in 120 seconds with one pump in use. Each cycle includes a 10-second rest period at the hangar and flight decks for loading or unloading. When the main elevator is operating on either of the cycles with two pumps in operation, the residual capacity of the system is such that upon failure of electric power, the platform with its specified load for the cycle may be lowered to the hangar deck, unloaded, and the empty platform returned to the flight deck, provided that the time between power failure and residual power operation does not exceed 30 minutes. The travel time from the hangar deck to the flight deck under this condition should not exceed 120 seconds.

Direct Plunger Lift Elevators

The platform of the direct plunger lift type elevator is raised and lowered by direct connection under the

platform, with one or two vertical hydraulic rams. Oil from a high-pressure tank, at a pressure of approximately 950 psi, is directed into the ram during the hoisting operation. Lowering is accomplished by the oil being discharged from the rams into an exhaust tank, which is under a pressure of approximately 230 psi. Pressure is maintained in the pressure tank by means of variable-stroke pumps, which take suction from the exhaust tank. One of the pumps is capable of maintaining elevator operation at reduced speed.

The direct plunger lift elevators may be considered as pneumatic-hydraulically actuated. On top of the confined hydraulic fluid in the high pressure tank there must always be an inert gas under high pressure.

Special control valves (operated by pilot valves or a motor), in the pressure and exhaust lines, regulate elevator speeds by varying the amount of oil admitted to or discharged from the rams. Positive stops and mechanical locks, interlocked with the elevator control system, enable the platform to be stopped, locked, and held in position at the flight deck level. An equalizer system maintains the platform at uniform level under conditions of unequal loading. Automatic quick-closing valves in the oil line prevent an unrestricted fall of the elevator. In case of damage to the main pumps, the sump pumps will generally provide sufficient power for one upward run; otherwise, the emergency run is made with the reserve capacity of the pressure tank. A hand control system is provided for use when electric controls are damaged.

Auxiliary Elevators

To provide adequate working space on the hangar deck while the elevator platform is at the flight deck level, a small auxiliary pit elevator is often provided. This elevator is raised and lowered simultaneously with the main elevator. The operating pistons receive power from the same pressure tank and discharge into the same exhaust tank as used by the main elevator. In some cases,

auxiliary elevators are provided with a separate electromechanical drive.

Plunger-Actuated Cable Lift Elevators

The plunger-actuated cable lift elevator is raised by wire-rope cables fastened to the platform at two or four symmetrically placed points. These cables, through a series of sheaves, are actuated by a horizontal hydraulic ram located beneath the hangar deck. Instantaneously acting safety devices engage the guide rails of the elevator, to stop and hold the platform in case one group of cables should fail.

Deck Edge Elevators

One type of plunger-actuated cable lift elevator is the deck edge elevator. The deck edge elevator is cantilever-supported over the side of the ship with a hinge arrangement for stowage in a vertical position. The outboard section of the platform is lifted to its stowed position by a special rigging arrangement. Vertical movement is imparted to the platform by two sets of cables attached to the inboard corners. These cables are actuated in a manner similar to that employed on the inboard elevators described under the plunger-actuated, cable lift elevators.

Electromechanical Elevators

The platform on electric elevators is raised and lowered by two groups of cables which pass over sheaves and thence to the hoisting machinery. Two hoisting drums, coupled together, are driven through a reducing gear unit by an electric motor. The motor is of the two-speed type (full speed and one-quarter speed). Control arrangements are such that the elevators start and run on the motor high-speed connection, the low-speed being used for deceleration as the elevator approaches the upper or lower limit of travel. The platform travels on two athwartship guides. Manually-operated locks equipped

with electrical interlocks are provided for holding the platform in the raised position.

Electrically-driven elevators are capable of hoisting a 7800 pound airplane plus a 1000 pound truck plus 500 to 1000 pounds in personnel at approximately 50 fpm.

MAINTENANCE OF ELEVATORS

Frequent inspections should be made of the elevator cables and fittings, and equal tension of the individual cables in each group maintained. The hydraulic fluid used generally approximates oil with the viscosity range of oil symbol 2075, suitable for operation at a maximum temperature of 135°F. Elevator hydraulic fluid is being replaced by a synthetic oil which is fire and explosion resistant. Be sure all pressure lines are kept tight, so that the cycle of operation will not exceed the designed period. Inspect frequently to ensure that there is proper oil level in pressure and exhaust tanks, no excessive leakage in sump leak-off connections, proper seal of the pistons in the hydraulic cylinders, and cleanliness of the entire hydraulic system.

CARE OF HYDRAULIC SYSTEMS

The integration of individual hydraulic systems with the various types of auxiliary equipment has been discussed thus far. Now, you should get a general perspective on the care and maintenance of these systems. Descriptions of the hydraulic variable speed gears employed for driving or controlling the auxiliary machinery are discussed in connection with positive displacement rotary pumps in an earlier chapter. These hydraulic-power transmissions provide great refinement of control, including reversal of the driven auxiliary, without perceptible steps in speed adjustments, as well as having the other advantages already covered. The overall efficiency of these speed-gear installations is dependent upon their size, oil pressure, speed, and stroke. But, in all cases,

the efficiency of the gears and the hydraulic system as a whole will depend upon the upkeep and care that are given them.

Avoid Corroded Gears

The hydraulic variable-speed gears should be kept full of oil at all times, to guard against corrosion. Otherwise, moisture may enter the case through the air vent on the expansion box and condense, thereby causing rust, which may eventually jam the working parts. Occasional inspection is necessary to ensure proper oil level. Repair of gear, except for small glove valves, is generally done in a Navy yard or by the manufacturer.

Keep Systems Air-Free

Every cavity in a hydraulic transmission system and a hydraulic steering gear system must be filled with oil to exclude all air. When the systems are being filled, vent plugs at the high points should be left open until all the air escapes and then closed to avoid waste of oil.

Before the system is started under power, it is well for the gears to be turned over slowly by hand to work the air out of the system. Otherwise, the air is likely to be whipped up into small bubbles which would escape very slowly. Hand-turning should continue as long as any air bubbles are seen escaping in the expansion box or at any of the bleeder plugs.

Cold Weather Operation

For hydraulic equipment located in exposed spaces above decks under cold weather conditions, pumps should be operated at no load until the oil has had a chance to warm up. In some instances it may be necessary to use a special cold weather hydraulic oil and to connect up special oil immersion heaters in sump and storage tanks, prior to operation of the equipment.

QUIZ

1. When are machines said to be hydraulic?
2. What three general types of steering gears may be found on naval ships?
3. What two types of remote control are utilized for the control of steering gears on most modern naval vessels?
4. In filling a hydraulic telemotor system what must be done before the replenishing oil is allowed to spill into the replenishing tank?
5. When a telemotor system is exposed to low ambient temperatures, what should be the approximate cold pour point of the mineral oil used?
6. Why should the hydraulic oil be strained through four to six layers of cheesecloth when a charging tank of a control system is being filled?
7. What component part of the pump regulates the rate of fluid delivery in an electrohydraulic steering gear?
8. What should be used to protect the exposed portions of the hydraulic rams of an electrohydraulic steering gear from corrosion?
9. How often should the oil in a steering gear, high-pressure hydraulic system be completely filtered?
10. How often should a steam-driven steering gear be turned over when the ship is not under way?
11. What two types of gears are employed in steam-driven and electromechanical steering gears?
12. What provides the reversibility of steam engines used for driving winches or capstans?
13. In addition to lubricating a steam-operated winch and disengaging the drum clutches prior to use, what else must be done?
14. What are the two general types of electrohydraulic elevators which you will find used by the Navy?
15. What prevents an unrestricted fall of a direct-plunger lift type electrohydraulic elevator?
16. At what maximum temperature is the hydraulic fluid used for electrohydraulic elevator systems suitable for operation?

17. How is the sticking of a shuttle valve in a hydraulic system usually indicated?

18. If steering control is lost from the pilot house, how can steering still be maintained?

19. An electrohydraulic crane cannot be started unless the controls are in which position?

CHAPTER 14

INDUSTRIAL GASES

Historically, the first gas to be put to large-scale commercial use was coal gas, obtained by distilling coal in retorts. In this process, coal is heated in vessels which shield it from air, and thereby prevent combustion, thus driving off gas from the coal, leaving coke. The city gas industry developed so rapidly in the last century, especially in England, that to most people the word "gas" became synonymous with the cooking, heating, and lighting gas mixture supplied by the gas companies. Coal gas is known as "producer gas"; oil gas is known as "natural gas"; their chief components are METHANE and other HYDROCARBONS. Hydrocarbons, as the word itself signifies, are compounds formed of carbon and hydrogen. Similar gases are developed in the process of "cracking" oil to produce gasoline, and those gases are known as "cracker gases."

After many generations of breathing the atmosphere, we have finally found (in the last 50 years) many important industrial uses for it. Air consists mostly of oxygen and nitrogen, plus small percentages of the inert gases, argon, neon, krypton, and xenon. We now have ways of separating these constituents of the atmosphere and putting them to work.

Only a few Machinist's Mates are engaged with the actual generation or compression of industrial gases, and those only after special training. All men of this

rating, however, are required to handle one or all of the several compressed gases used aboard ship. It is important, therefore, that you have a general understanding of the characteristics as well as the uses of these gases.

GENERAL NATURE OF GASES

Before discussing the physical properties and characteristics of specific gases, let's briefly summarize the general nature of gases.

ALL GASES ARE COMPRESSIBLE; that is, they can be forced into spaces of lesser volume than they occupy under normal conditions. Then, you will also recall two GAS LAWS which express the relationship of the gas pressure with its volume and temperature. BOYLE'S LAW states that the volume of a confined body of gas varies inversely as the absolute pressure, provided the temperature remains constant. In other words, when the pressure is increased the volume decreases, and when the pressure is decreased the volume increases. CHARLES' LAW states that the volume of gas expands as its temperature is increased, if the pressure is kept the same. This law also states that the pressure of a gas is increased when the temperature is increased, if the volume of space occupied is kept the same. In the actual work of compressing and handling gases, the temperature, volume, and pressure are all changed at one time or another.

The TEMPERATURE FACTOR is important in handling gases, for when the temperature of a gas in a container is increased, the pressure increases on all parts of the container. Consider an automobile tire, for example. The air in the revolving tire gains heat from the warm pavement, and from friction. This added heat energy increases the molecular activity of the air within the tire. The tire appears to have accumulated more air, as indicated by the increased pressure against the tire walls (the tire actually expands due to the increased pressure). Let the tire cool, however, and the pressure returns to normal.

Gas cylinders are not elastic and do not expand from

the pressure of the gas within them. Cylinders are, therefore, filled with compressed gases only to the maximum safe pressures at normal atmospheric temperatures. Storage of the cylinders in hot spaces will increase the pressure of the confined gases to a dangerously high point, where the cylinders will explode.

The boiling points for the various liquified gases is important, as will be explained later on. Various gases have to be separated from each other. Their different boiling points make this possible. As an illustration of this principle, take a mixture of water and alcohol in an automobile radiator. Alcohol boils at 172° F, but water boils at 212° F; the alcohol therefore begins to evaporate and separate from the water before the water nears the boiling point. As the water is never allowed to reach 212° F, the alcohol content grows less and less as the temperature rises above 172° F. The same process is employed in separating and purifying gases.

SPECIFIC GAS CHARACTERISTICS

In addition to knowing the general nature of gases, you should know some of the distinguishing features of the gases utilized by the Navy, and the special precautions to be exercised in handling industrial gases. From a standpoint of volume used by the Navy, the gases oxygen, carbon dioxide, acetylene, and freon lead all others by far. The first three gases will be discussed in some detail; then the other Navy stock gases will be discussed briefly. To keep them in some order, without going into the question of their importance, the first three, and then the remaining gases, will be discussed in alphabetical order. Included in the discussion are the safety precautions to be followed when handling each of the industrial gases.

Acetylene

Acetylene is a chemically produced gas which is not found in the natural state. Its ability to produce high

temperatures when combined with oxygen (burned) was discovered in 1895. In 1892 a method for the commercial production of the chemical CALCIUM CARBIDE was discovered. It is from calcium carbide and water that acetylene gas is produced. By the turn of the century, acetylene was being used for lighting, both commercially and domestically. Even today acetylene is used in lighthouses and buoys because of its exceptional brilliance while burning.

Acetylene (C_2H_2) is a colorless gas. When pure it has a sweet odor, but when impure, usually with HYDROGEN SULPHIDE as an impurity, it has a disagreeable odor. Hydrogen sulphide is the gas that produces the well known "rotten eggs" smell. Acetylene is shipped dissolved in ACETONE in cylinders that contain a MONOLITHIC filler. Acetone is a liquid ORGANIC compound which is used as a solvent for many other organic compounds. Roughly, an organic compound is any one that contains carbon (C); note that acetylene (C_2H_2) is an organic compound formed by combining two atoms of carbon with two atoms of hydrogen. Monolithic, as used here, means that the cylinder is filled throughout with the same mixture of asbestos, charcoal, cement, and diatomaceous earth. Diatomaceous means composed of the skeletons of various forms of sea life.

Acetylene is stable and safe to handle as charged in Navy standard acetylene cylinders. But in the free gaseous state, or if compressed in cylinders not designed for acetylene, the gas is very unstable and likely to decompose violently. In large volumes, at pressures exceeding 15 psi, acetylene is dangerously explosive. This means that acetylene can "explode of its own accord" when improperly stored or handled. It does not always need air, or oxygen, or a spark to help it explode. Any shock or heat may be enough to set acetylene off if it is stored at pressures higher than 15 psi.

When mixed with air or oxygen, the chances of violent explosion are doubled. The explosive limits of acetylene

in air range from 3 to 12 percent acetylene by volume, with maximum effect at approximately 7.8 percent. Acetylene in copper piping systems, or in piping systems with silver brazed joints, may form acetylides by combining with copper or silver. Acetylides so formed are violently explosive and are capable of being detonated by shock or heat.

Acetylene mixed in controlled proportions with oxygen in the acetylene torch produces an intensely hot flame. Its uses in welding and cutting are too well known to be discussed here. The safety precautions, however, should be emphasized again and again. You will be held strictly accountable for knowing and observing those rules yourself, and you should make every effort to see that others handling acetylene know them and follow them.

Safety Rules for Acetylene

1. Acetylene should never be discharged into hose lines, manifolds, etc., at a pressure greater than 15 psi. A suitable pressure-reducing regulator should be employed on all occasions. Acetylene is inherently unstable and, at pressures greater than 15 psi, may disassociate violently when subjected to heat or shock.

2. Acetylene cylinders should be used or stored only in an upright position, valve end up, to avoid the possibility of withdrawing acetone when the cylinders are being discharged. Don't open the cylinder valve more than 1½ turns of the spindle.

3. Do not recharge acetylene cylinders or transfer acetylene from one cylinder to another without specific approval from the Bureau of Ships. It is possible to charge or refill acetylene cylinders safely only with special equipment. Acetylene cylinders contain, as we have said, a porous material with minute cellular spaces, so that no pockets of appreciable size remain where free acetylene in the gaseous state may collect. In addition, acetone partially fills the cellular spaces and acts as a solvent for the acetylene. While in the dissolved state,

acetylene is stable. It should be clear by now that no other type cylinder should be used to store acetylene gas.

4. Keep sparks and flames away from acetylene cylinders, and under no circumstances allow a flame to come in contact with the safety devices. Never allow the cylinders to contact electric welding apparatus or electrical circuits.

5. Where it is necessary to test for leaks, use soapy water.

6. Do not interchange acetylene regulators, hose, or other appliances with similar equipment intended for other gases.

7. Do not use acetylene manifolds which are not approved by the Bureau of Ships.

8. Use no wrench other than the one designed for opening the cylinder, and keep the wrench on the cylinder while it is in use.

9. Should a cylinder catch fire, use a wet blanket to extinguish the fire; if this fails, spray a stream of water on the cylinder.

Carbon Dioxide

Carbon dioxide (CO_2) is a colorless, odorless gas 1.52 times as heavy as air. It can be condensed into a colorless liquid and stored in this state, under pressure, in cylinders. When the cylinder valve is opened, gaseous CO_2 escapes and, due to the rapid drop in pressure and temperature, forms carbon dioxide snow. This snow, when compressed into blocks or cubes, is what we know as "dry ice." Dry ice, in solid form and at atmospheric pressure, volatilizes, remaining at $-110°$ F until it has disappeared. It is excellent for certain refrigeration uses.

Because it will neither support combustion nor form explosive mixtures, CO_2 is one of the chief fire-extinguishing agents in use today. It is also used for inflatable gear such as life rafts and vests, and as a propellant or expelling agent.

Carbonated soft drinks contain carbon dioxide dis-

solved in water and kept under pressure in the container. When this pressure is relieved, CO_2 bubbles will rise to the surface.

There are many natural carbon dioxide wells in the earth's surface. Yellowstone National Park has several of these wel's, and in some of the park's caves the CO_2 is so dense that animals are suffocated when they wander into them. Since CO_2, in addition to being heavier than air, is both invisible and odorless, it presents a particular hazard. As in the caves, it will tend to collect in low, unventilated places which might well be below decks on shipboard for instance. The fact is obvious that the more of any other gas, poisonous or not, that is present, the less breathable oxygen there will be present. Men going into these conditions or places, or left there, run the risk of smothering to death.

Small percentages of carbon dioxide will cause tiredness and perhaps headaches. Three percent in the air doubles breathing effort, and 5 percent causes panting. Eight percent causes marked distress and 10 percent causes unconsciousness very quickly.

Treatment of personnel exposed to CO_2 includes removal from the CO_2-laden atmosphere, artificial respiration (if necessary), administering oxygen, and keeping the patient warm and quiet.

Safety Precautions for Carbon Dioxide

1. Do not enter an area or compartment containing hazardous amounts of carbon dioxide without being equipped with a breathing mask and an independent supply of oxygen.
2. If this is not practicable, and the case is urgent, enter only when equipped with a life line and with an assistant standing by outside the area or compartment.

Oxygen

Oxygen (O_2) makes up almost one-half of all matter that we know. Water contains, by weight, about 89 per-

cent oxygen. Clay, sand, limestone, and granite contain about 50 percent. ONE-FIFTH BY VOLUME OF THE AIR IS OXYGEN. This is the only occurrence of free oxygen, this one-to-five mixture in the air; elsewhere it is found in compounds.

Oxygen is a colorless, odorless gas which does not itself burn, but which supports the combustion of other things. Even steel will burn in pure oxygen.

Oxygen is normally shipped in a gaseous state, contained in cylinders and identified as one of two types: (1) aviators' breathing oxygen or (2) industrial or technical oxygen. There is absolutely no difference in the purity of the oxygen itself in these two types. The only difference is in the moisture content of the cylinders. Cylinders containing aviators' breathing oxygen have been dried inside, before being charged. This prevents failure of breathing apparatus due to the formation of ice under high altitude freezing conditions.

To simplify the supply system, aviators' breathing oxygen is the only kind stocked by ships and is used on shipboard for welding and cutting operations as well as for breathing purposes.

Industrial or technical oxygen, supplied for nonshipboard use in welding and cutting operations, can be and is used for breathing purposes, other than aviation, because its purity is identical with that of aviators' breathing oxygen, and freezing conditions at low altitudes either do not exist or can be eliminated.

The manufacturing process by which oxygen is generated is a good example of how the Navy uses the distillation process in the production of compressed gases. In the process, air is cooled and compressed until it is liquefied. This liquefied air is then boiled to allow those composite gases with low boiling points to separate from the liquid mixture. These separated gases are sometimes saved as by-products of the process, or they may be simply released to the atmosphere. Oxygen is used for charging

oxygen tanks for breathing during battle emergencies, deep diving or high altitude flying; for cutting and welding; and for medical purposes in asphyxiation, sea sickness, pneumonia, electric shock, sunstroke, etc.

Safety Rules for Oxygen

1. Never permit oil, grease, or other readily combustible substances to come in contact with oxygen cylinders, valves, regulators, gages, and fittings. Contamination with hydrogen, oils, or grease may result in a serious fire or explosion.
2. Never lubricate oxygen valves, regulators, gages, or fittings with oil or other flammable substances. Do not handle oxygen cylinders or apparatus with oily hands or gloves.
3. Never use oxygen from a cylinder without reducing the pressure through a suitable regulator.
4. Use only approved oxygen regulators, hose, and other appliances.
5. Never attempt to use oxygen cylinders for other than oxygen service.
6. Never use oxygen as a substitute for compressed air. It is dangerous to use oxygen for pneumatic tools, for starting diesel engines, for building up pressure in oil reservoirs, for paint spraying, for blowing out pipelines, and similar purposes for which compressed air is normally used.
7. Never use compressed oxygen or any other compressed gas for cooling the body or for blowing dust from clothing.

OTHER IMPORTANT GASES STOCKED BY THE NAVY

The gases noted here are in sufficient stock in the Navy to warrant mention in this training course. Once again, remember that the listing is in no way indicative of the volume or importance of these gases; it is simply alphabetical.

Aerosol (Insecticide)

Aerosol, as charged in standard Navy cylinders, is a safe nonflammable material, having a maximum of 22 percent nonvolatile ingredients by weight, and is of the following general composition:

Pyrethrum extract, 2 percent.
DDT (dichlorodiphenyltrichloroethane), 3.0 percent.
Solvent for DDT, 15 percent.
Freon-12 (dichlorodifluoromethane), 80 percent.

Though aerosol is safe and nonhazardous to personnel as normally used, it has toxic properties if inhaled in sufficient quantities. This is indicated by the fact that aerosol is lethal to small birds, fish, and other low-order forms of life.

See Freon (page 553) for safety rules pertinent to aerosol. You must remember that DDT, pyrethrum, and the solvent for DDT, in ordinarily used quantities, are relatively harmless to most humans. However, these insecticides, if inhaled in large quantities or applied to the skin, can cause dizziness and serious sickness.

Air (Compressed)

Compressed air, as charged in Navy-owned cylinders, is normally oil free, and when supplied by the Naval Shipyard at Norfolk or Puget Sound, is dried and suitable for use in applications where a low water vapor content is necessary.

The safety precautions with regard to compressed air are much the same as for the other compressed gases. Of course, compressed air is neither poisonous nor flammable, but at the same time you should not become careless in handling it. Compressed air tanks, lines, and fittings have exploded, injuring men and property. Literally thousands of careless men have blown dust or harmful specks into their eyes by the careless handling of compressed air outlets. Because compressed air seems so safe in comparison with the other gases, do not let overconfidence lead to your own or someone else's injury.

Ammonia

Ammonia (NH_3) is a colorless gas, lighter than air, with the characteristic shocking odor of smelling salts. As shown by the symbol, it is a compound of one atom of nitrogen with three atoms of hydrogen. It is an irritant and can cause acute distress by attacking the tissues of the respiratory tract, the skin, and the eyes. Exposure to large quantities is fatal. Dissolved in water, it forms the ammonia water you may have used for cleaning purposes.

Vast quantities of ammonia are required for a variety of industrial uses, including refrigeration. Ammonia is used as a solvent, as a deodorant in cleaning, in rubber processing, in medicine, and for surface hardening or NITRIDING of steels. Smelling salts are carbonates of ammonia. ANHYDROUS AMMONIA is purified ammonia gas, liquified under pressure, and put in cylinders. Ammonia does not burn in air, but a mixture of ammonia and oxygen or air can explode when ignited.

Safety Rules for Ammonia

1. Should it become necessary to transfer ammonia from refrigeration systems into cylinders, care should be taken to avoid overcharging these cylinders. Only empty ammonia cylinders should be used for this purpose, and to ensure that they are empty, their valves should be opened and the cylinder vented out of doors. Prior to attaching the cylinders to systems which are to be emptied, the cylinders should be carefully weighed and the tare weights (empty weight) noted. The cylinders may then be connected to refrigeration systems for filling, but should be weighed from time to time while being filled in order that not more than the appropriate weight of gas is charged in the 50- or 100-pound cylinders. If any cylinder is accidentally overfilled, the excess gas should be discharged

slowly into water, preferably in the open, where any escaping gas vents to the atmosphere.

2. When cylinders that are used to store ammonia withdrawn from refrigeration systems are later returned to supply depots for refilling, they should be tagged with the explanation that the cylinders were so used.
3. Ammonia gas is lighter than air. Therefore, in going to the rescue of a person overcome by ammonia, keep as near to the deck as possible. The usual Navy-issue gas mask (ND Mark 4) is unsuitable for rescue work in ammonia-filled compartments or spaces—oxygen rescue breathing apparatus must be used when entering such spaces.
4. Treatment of personnel exposed to ammonia fumes.
   a. Summon the medical officer promptly. If the eyes are affected, and the medical officer is not promptly available, hold the lids open and pour water over the eyeballs and lids, irrigate the eyes thoroughly.
   b. If the skin is affected, strip the ammonia-saturated clothing from the patient. Wash affected areas with water, then paint burned surfaces with a saturated solution of picric acid. Do not cover burns with clothing or dressings without the approval of the medical officer.
   c. If the nose and throat are affected, irrigate and spray nostrils with normal saline (a weak salt-water solution) if available; if not, plain water is satisfactory. Encourage patients to drink large amounts of water.

Argon

Air, as was mentioned earlier, is a mixture whose volume consists mostly of oxygen (20.99 percent) and nitrogen (78.03 percent). The remaining 1 percent is made up of argon (0.94 percent) and traces of other gases

such as neon and helium. Argon is slightly heavier than the rest of the air with which it is mixed. Argon is an inert element; that is, it will not combine with other substances. Accordingly argon will not burn, will not support combustion, and will not explode. As far as we are concerned argon is just pure filler material, neither affecting nor being affected by anything around it. This inertness of argon invests it with certain special advantages. Its most common use is in electric light bulbs where the tungsten filament is surrounded by the argon. This prevents the filament from burning out as fast as it would in air, or in a vacuum, or in a nitrogen-filled bulb. Argon also is used in discharge illumination tubes (similar to neon tubes) and gives off a blue-violet color. These uses are only indirectly related to the Navy's industrial operations. The main use of argon in the Navy will probably be in the field of INERT GAS SHIELDED ARC WELDING.

A word might be said about inert-gas shielded-arc welding. Since an inert gas will not burn, sustain combustion, or combine in any way with the hot materials being welded, such a gas like argon or helium has an invaluable use as a "protective blanket" around the immediate area being welded. The inert gas protects the welding area from the atmosphere and hence prevents the formation of any unwanted oxygen or nitrogen compounds of the metal being welded.

Since argon is inert, and usually stored in small quantities, there are not as many safety precautions to observe in relation to this gas. However, the same care must be given it as must be given any gas under high pressure. Though it is not poisonous, it definitely will not support life, hence you must be careful never to confuse it with air or oxygen breathing tanks.

Carboxide

Carboxide is the trade designation for a gaseous mixture of 90 percent CO_2 and 10 percent ethylene oxide. As a mixture, these gases are not flammable in air, but

ethylene oxide by itself is explosive in air, as you will see later. Carboxide is commonly used as a fumigant throughout the service. It is obtainable, compressed to a liquid, in steel cylinders. When used, carboxide comes out of the cylinders as a fine spray or mist which vaporizes. Since carboxide is 1.52 times as heavy as air, it settles in low places. For information regarding its characteristics and safety rules, see the sections of this chapter relating to carbon dioxide and ethylene oxide. *Bureau of Ships Manual,* chapter 36, contains instructions for the use of carboxide.

Chlorine

Chlorine (Cl) is a heavy gas, 2.44 times as heavy as air, and is greenish-yellow in color. It is not flammable, but will react violently with ammonia or hydrogen. It has a highly disagreeable and irritating odor and is very poisonous. It was used as an antipersonnel gas in World War I. At normal pressures and temperatures it is a gas, but it is shipped as a liquid in steel cylinders. The Navy purchases all its chlorine already bottled from civilian manufacturers.

The military uses of chlorine are for water purification, sewage disposal, and in the preparation of bleaching solution.

Safety Rules for Chlorine

1. Chlorine should be used only by experienced and properly trained personnel. Where chlorine is used, good ventilation should be maintained and exposed personnel should be furnished with gas masks approved for protection against chlorine.

2. Where necessary, the presence of chlorine may be detected by using a cloth wet with AQUA AMMONIA (ammonia water); the ammonia in the presence of chlorine will produce white fumes.

3. If it is necessary to immerse chlorine cylinders in a bath of warm water to facilitate discharge, extreme care

must be taken not to generate a dangerous pressure in the cylinders. Be sure to maintain the temperature of the water below 130° F, lest the fusible plugs in the cylinder melt. In no event should the cylinder valve be submerged, nor should more than 20 percent of the surface area of the cylinder be under water.

4. Treatment of personnel exposed to chlorine fumes:
   a. If exposed to fumes, patients should be kept warm and quiet, covered with blankets if necessary. Rest is essential. Place patient on back with head and chest elevated. Call the medical officer immediately. Splashes of liquid chlorine, or chlorinated water, may cause skin irritation and burns. In either case, remove clothing immediately and wash exposed part of skin with copious amounts of water or soapy water.
   b. Start artificial respiration immediately, IF the person is not breathing.

Ethyl Chloride

Ethyl chloride is a gas of chemical composition C_2H_5Cl; that is, it is composed of carbon, hydrogen, and chlorine. It is a colorless, somewhat flammable gas known also as monochlorethane. Ethyl chloride is a gas at room temperature and pressure. It is poisonous if absorbed in sufficient quantity.

Medically ethyl chloride is used during minor operations in the form of a spray to produce local anesthesia by freezing. The rapid evaporation of the gas cools the skin to freezing, after which the flesh may be cut without pain. It is also used as an inhalant anesthetic for minor operations or for putting a patient to sleep before administering ether. The Navy purchases all its ethyl chloride as a colorless liquid compressed in cylinders. Ethyl chloride becomes a liquid at 54.5° F and therefore is not hard to liquefy by cooling.

The principal use of this gas is as a refrigerant. The

same safety rules apply to it as to the other combustible gases. These rules are outlined for acetylene. However, there is no hazard attached to ethyl chloride at pressures above 15 psi as there is to acetylene.

Ethylene Oxide

Ethylene oxide $(CH_2)_2O$, a compound of carbon, hydrogen, and oxygen, is approximately 1.52 times as heavy as air. It is flammable and explosive. Its explosive limits in air are from 3 to 80 percent by volume. It is slightly toxic and, if present in any appreciable volume, is an asphyxiant. Its primary uses are for insect control and for the manufacture of carboxide. Ethylene oxide is an excellent fumigant, for not only is it just slightly poisonous to man, but it will not harm delicate materials, textiles, foodstuffs, grain, and other similar materials.

Its safety rules are practically the same as those for acetylene, but it may be handled at pressures above 15 psi. Ethylene oxide is shipped as a liquid in steel cylinders.

Freon

The trade name Freon covers a group of refrigerants which are available commercially under number designations: Freon 11, 12, 22, and 114, for example: Freon 12, the most common, is chemically known as dichlorodifluoromethane, has the formula CCl_2F_2, and is composed of chlorine, carbon, and fluorine. The Freon refrigerants are nonflammable, nonexplosive, and nontoxic—nontoxic in concentrations normally encountered, but toxic in higher concentrations. However, in the presence of fire or red hot metal they decompose to form PHOSGENE, which is extremely toxic.

Because of its low boiling point, and other physical characteristics, Freon makes an ideal refrigerant. It is also used as a propellant for spraying DDT and other insecticides. The Freon, under pressure in the can-dispenser, sprays out into the air and carries the insecticide with it. Since Freon itself is nontoxic in concentrations

normally found on shipboard, it may be breathed in small quantities without harmful effects.

Chemically, it is inert at ordinary temperatures and thermally stable up to 1022° F. It is only slightly soluble in water. Leaks are detected by means of a halide lamp—an alcohol-burning torch that, under normal conditions, produces a colorless flame that turns bright green if the air contains 0.01 percent or more of Freon gas. The Navy purchases all its Freon from commercial producers.

Safety Rules for Freon

Freon cylinders are subject to the same handling and refilling rules that are given for ammonia cylinders, except that standard Freon cylinders are of 10- and 50-pound capacities.

1. Men who service Freon refrigeration systems should wear safety goggles to avoid the chance of liquid Freon coming in contact with their eyes and causing injury because of the freezing effect of the refrigerant.

2. Should a man be overcome by exposure to a high concentration of Freon, he should be removed immediately from the toxic atmosphere and medical help should be summoned at once. If the patient is not breathing, begin artificial respiration at once.

Helium

Like argon, helium is an inert gas. It is extremely light in weight. Only hydrogen is lighter than helium. Helium is colorless, odorless, and completely nonflammable and nonexplosive. It is particularly valuable for use in lighter-than-air aircraft, for while its lifting power is less than that of hydrogen, there is no fire hazard.

Helium is under the cognizance of the Bureau of Aeronautics and may be procured in two grades: (1) technical and (2) breathing, oil free.

Helium is used for inflation of lighter-than-air aircraft, barrage, and aerological balloons. It is useful in inert

gas arc welding (heliarc welding) and in inert gas applications similar to those for which nitrogen is used, such as optical instrument work. Here helium is used to fill spaces between lenses of such fine optical instruments as submarine periscopes, for purposes of both protection and increased accuracy. It is also used for breathing purposes, in mixtures with oxygen, by divers and caisson workers to help prevent the "bends" caused by working under extreme pressures.

Its safety precautions are similar to those for argon and compressed air.

Hydrogen

Hydrogen (H_2) is the lightest of all elements. It is odorless, colorless, and nonpoisonous. Hydrogen is extremely flammable. Mixtures of hydrogen and air containing between 5 and 75 percent of hydrogen by volume will explode when brought in contact with anything red hot. Pure hydrogen, if burned in air from a suitable burner, has a bright-yellow flame. A mixture of hydrogen and air with less than 10 percent of hydrogen by volume, if likewise burned from a suitable burner, has an almost invisible blue flame.

Hydrogen is used in welding, in underwater cutting operations, and for inflation of barrage balloons. The oxyhydrogen torch is used underwater in lieu of the oxyacetylene torch because of the explosive hazard involved in using acetylene at pressures in excess of 15 psi. The oxyhydrogen process, however, is gradually being replaced by the arc-oxygen cutting process.

The same safety rules apply to hydrogen as apply to acetylene, except that pressures over 15 psi may be used, and great care must be taken to guard against leaks. Hydrogen has a way of leaking through all but the best fittings. Never use a flame to detect leaks. Use soapy water or, during freezing weather, linseed oil. Store the cylinders in a well ventilated place separated by a fire-resistant partition, and never near oxygen cylinders.

The gas is sometimes used for underwater cutting and welding.

Liquid Petroleum Gases—Butane, Propane

Liquid petroleum gases are usually colorless and odorless in their normal state. It is common practice to odorize these gases artificially to provide for quick detection of leaks and thus to safeguard personnel. The odor agent usually employed causes a "rotten cabbage" smell. Propane and butane are not poisonous, although their fumes have an intoxicating effect similar to that received from gasoline fumes. They are flammable when mixed with air in certain proportions: (2 to 7 percent) and under certain conditions may, when ignited, cause explosions similar to those produced by gasoline. Since they are heavier than air, they will seek ground level and settle in pits. They are primarily used for domestic cooking, hot-water heating, and refrigeration. Industrially they are used with oxygen in the same manner acetylene is used for cutting metals. They are, however, not as fast, since they produce a lower temperature with the oxygen in the preheating flame than the oxyacetylene flame. Aboard ship, liquefied petroleum is used principally in medical and dental laboratories.

The liquid petroleum gases are purchased from commercial sources by the Navy. Their safety precautions are the same as for acetylene, except that they may be piped at pressures over 15 psi.

Methyl Chloride

Methyl chloride (CH_3Cl) is a colorless, noncorrosive gas which is transparent in both the gaseous and liquid states. It has a faintly sweet, ether-like odor. It is not irritating to the eyes or lungs, but has an anesthetic effect if breathed. It is flammable and presents a moderate explosive hazard. The explosive limits of methyl chloride in air are from 8.1 to 17.2 percent. It is used principally for refrigeration.

Methyl chloride is a solvent for most organic materials; so composition gaskets used with it must be selected carefully. In general, they should not contain rubber or neoprene. Pressed asbestos and metallic gaskets may, of course, be used. The Navy purchases its methyl chloride from commercial sources.

The safety precautions for methyl chloride are practically the same as for acetylene, except that pressures above 15 psi may be used. Sometimes 1 percent ACROLEIN, a highly irritating gas, is added as an indicating agent; then gas leaks are very noticeable, stinging the nose and eyes. Methyl chloride does not harm most articles of food, but it definitely should not be breathed in any concentration or for any length of time. A 2–percent concentration breathed for over 2 hours will cause death, while only a few breaths of higher concentrations can lead to a dangerous loss of consciousness.

Nitrogen

For our purposes, nitrogen (N_2) is considered to be an inert gas. It is not completely inert like helium or argon, for there are many nitrogen compounds such as the nitrates used in fertilizers and explosives. However, nitrogen is very slow to combine chemically with other elements under normal conditions. This is clearly seen when you consider that four-fifths of the atmosphere is always nitrogen, and therefore it is always around when things are happening, and yet it rarely mixes into things. The oxygen in the air gets directly into fires, into rust, into living things, and into the "oxidation" of many substances. But nitrogen, as a gas, supports no fires, no living things, and causes no rust or decay of most of the things with which it comes in contact. By chemical and electrical processes it can, and is, taken from the air and combined with other substances. Such processes are known as "nitrogen-fixation."

In the Navy, nitrogen is used for pressure-operated mechanisms such as recoil systems, as an expellent in

flame throwers, in optical instrument applications, for testing pipelines, and as a gas-blanket if required, as in atmospheric controlled furnaces, and for preservation packing. Nitrogen for naval use is pumped by a water-lubricated compressor and is specially dried. Nitrogen cannot be used for inert-gas-shielded welding because the high temperatures involved can cause nitrogen to combine with other substances.

Nitrogen is slightly lighter than air, and, as indicated, is neither flammable nor explosive. It is not poisonous, but unless oxygen is mixed with it, it is an asphyxiant. Nitrogen gas is obtained by the fractional distillation of air. On aircraft carriers, nitrogen is a byproduct of the oxygen plant. The nitrogen is utilized extensively on these vessels for maintaining an inert blanket over aviation fuel and other special fuels in their respective storage tanks.

The safety precautions for nitrogen are similar to those for argon, helium, and compressed air.

Nitrous Oxide

Nitrous oxide, or nitrogen monoxide (N_2O), is a colorless gas with a pleasant odor and a sweetish taste. It has also been called "laughing gas" because it may cause bursts of laughter when inhaled. It is used as an anesthetic and is particularly useful for obtaining anesthesia rapidly for operations of short duration.

The safety precautions for nitrous oxide are the same as for any other nonflammable, nonexplosive, compressed gas. Since it can cause anesthesia, and death if breathed in large amounts, care must be taken not to inhale it.

CONSTRUCTION AND MARKING OF CYLINDERS

With respect to the gas cylinders themselves, you should have a general idea of their construction, design, and size; how to identify the cylinders of various gases, and the construction and use of their valves and regulators.

Cylinder Design and Size

Gas cylinders are made of high-quality steel. For high-pressure gases, such as oxygen and hydrogen, cylinders are usually of seamless construction. For low-pressure gases, such as acetylene, the cylinders may be welded or

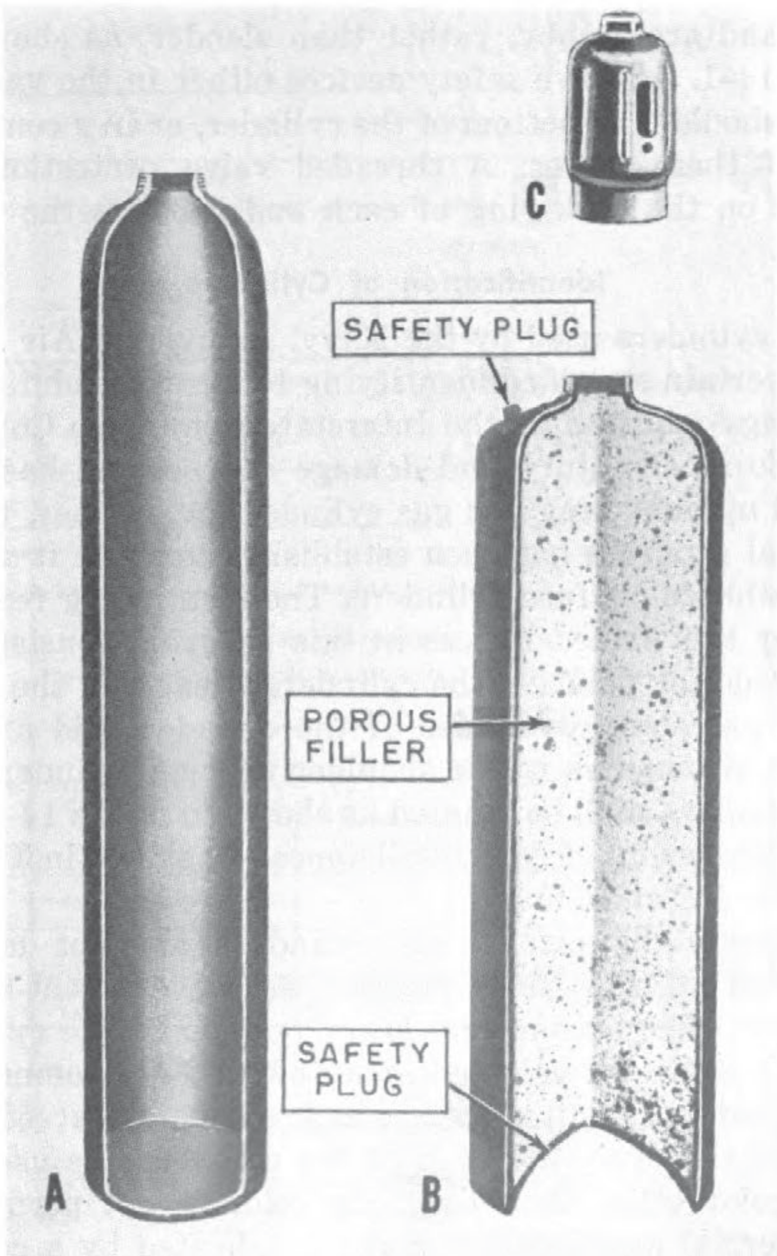


Figure 14–1.—Cutaway view of compressed gas cylinder: (A) oxygen cylinder, (B) acetylene cylinder, (C) valve protection cap.

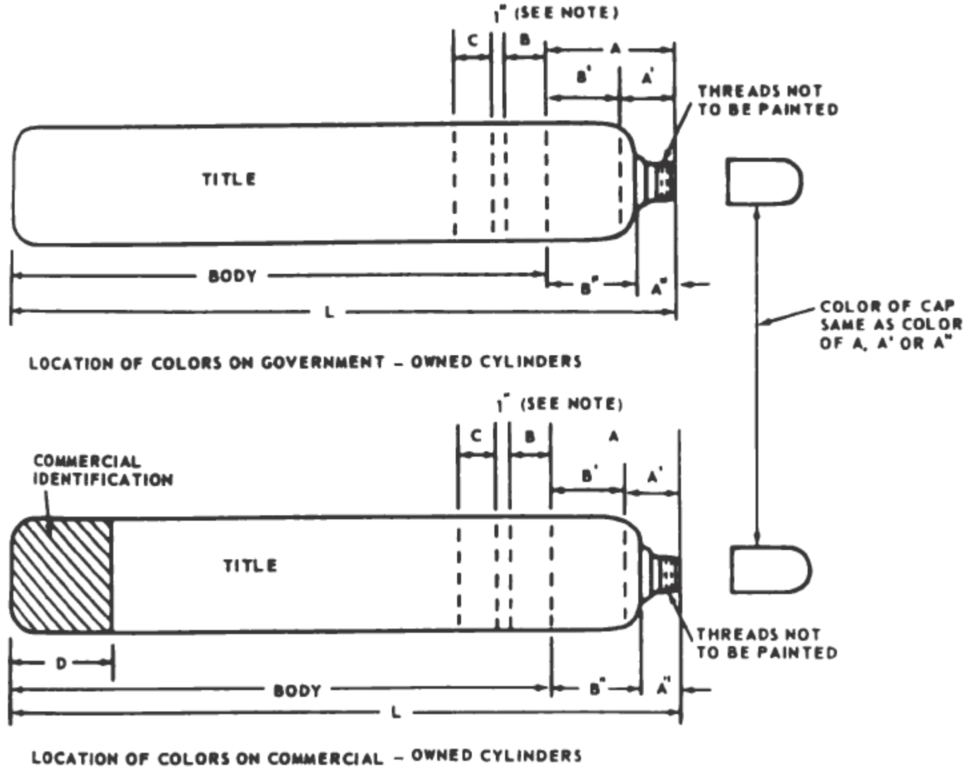
brazed. All cylinders are carefully tested at pressures above the maximum permissible charging pressure.

Gas cylinders are substantially the same, except those for acetylene, which differ in that they have either recessed or slightly rounded tops, rather than fully rounded. Acetylene cylinders are completely filled with a porous material impregnated with acetone, which acts as a solvent; and are stubby, rather than slender, as shown in figure 14–1. All have safety devices either in the valve or in the shoulder or bottom of the cylinder, or in a combination of these places. A threaded valve protection cap screws on the neck ring of each and protects the valve.

Identification of Cylinders

Gas cylinders used by the Navy, Army, and Air Force carry certain standard identifying features in addition to markings required by the Interstate Commerce Commission. So much injury and damage can be, and has been caused by mistaking one gas cylinder for another, that a national program has been established to make it almost impossible to confuse cylinders. The identifying features used by the Armed Forces in this program consist of a color code for painting the cylinders, stenciling the name of the gas along two sides of the cylinder, and affixing two decalcomanias to the shoulder of each cylinder. The gas cylinders shall be painted as shown in figure 14–2 and the arrangement of colors will appear as shown in Table 3 on pages 562 and 563.

Commercially owned gas cylinders are not usually identified in the same manner as Government-owned cylinders. The bottom and lower portion of the cylinder body opposite the valve end may be used for commercial identification. In this area, which shall not exceed one-sixth of the over-all length of the cylinder, the use of a solid color other than the body color is not permitted. Commercial identification may be indicated by a colored design or pattern such as dots, squares, diagonal stripes, etc.



LOCATION DIMENSIONS

ON CYLINDERS FOR MEDICAL GAS MIXTURES, 1" SPACE AND BAND C ARE LOCATED IMMEDIATELY BELOW BANDS B' OR B"

CYLINDERS FOR	OVERALL LENGTH	SHOULDER COLOR(S)			CYLINDER COLOR BAND (S)				COMMERCIAL IDENTIFICATION
		A	A'	A"	B	B'	B"	C	D
MEDICAL GAS MIXTURE	OVER 30"	L/5	3½"	—	—	AL ESS 3½"	—	3"	L. 6
OTHER GASES	"	L/5	—	—	3	—	—	3"	L/6
MEDICAL GAS MIXTURE	30" AND UNDER	L/5	—		—	—	AL ESS A"	2"	L/6
OTHER GASES	"	L/5	—	—	2	—	—	2"	L/6

FROM CYLINDER TOP TO BOTTOM OF NECK RING

NOTE: 1" SPACE TO BE OMITTED IF BANDS B & C ARE OF DIFFERENT COLORS

Figure 14-2.—Location of color codes on gas cylinders.

If the camouflage scheme of a ship is adversely affected by the cylinder colors, canvas covers painted with the camouflage colors shall be put over the cylinders.

Shatterproof cylinders shall be stenciled in two locations with the phrase "Non-Shat" longitudinally and 90° from titles. Letters shall be black or white and approximately 1 inch in size.

TABLE 3.—CYLINDER COLOR CODE

Contents of cylinder	Location of cylinder markings			
	Top A	Band B	Band C	Body
Medical anesthetic gases:				
Cyclopropane	Orange	Yellow	Blue	Blue
Ethylene	Yellow	Blue	do	Do.
Nitrous oxide	Blue	do	do	Do.
Fuel gases:				
Acetylene	Yellow	Yellow	Yellow	Yellow
Hydrogen	do	Black	do	Do.
Manufactured gases	Brown	Yellow	do	Do.
Petroleum (liquefied & nonliquefied).	Yellow	Orange	do	Do.
Industrial gases:				
Butadiene	do	White	Buff (tan)	Buff (tan)
Ethylene oxide	do	Blue	do	Do.
Ethyl chloride	Buff	do	Yellow	Do.
Propylene	Yellow	Gray	Buff	Do.
Vinyl chloride	do	Orange	do	Do.
Vinyl methyl ether	do	Black	do	Do.
Aerosol insecticide	Buff	Buff	do	Do.
Carboxide	do	Blue	do	Do.
Toxics and poisonous materials:				
Carbon monoxide	Yellow	Brown	Brown	Brown
Hydrogen sulfide	Brown	Yellow	do	Do.
Methyl bromide	do	Black	do	Do.
Boron trifluoride	Gray	Brown	do	Do.
Chlorine	Brown	do	do	Do.
Hydrogen chloride	do	White	do	Do.

TABLE 3.—CYLINDER COLOR CODE—Cont.

Contents of cylinder	Location of cylinder markings			
	Top A	Band B	Band C	Body
Toxics and poisonous materials: Continued				
Phosgene	do	Orange	do	Do.
Sulfur dioxide	do	Gray	do	Do.
Refrigerants:				
Ammonia	do	Yellow	Orange	Orange
Freons	Orange	Orange	do	Do.
Methyl chloride	Yellow	Brown	do	Do.
Oxidizing gases:				
Oxygen	Green	Green	Green	Green
Oxygen, aviator's	do	White	do	Do.
Air, oil pumped	Black	Green	do	Black
Air, water pumped	do	do	Black	Do.
Helium-Oxygen	Buff	White	Green	Green
Oxygen-Carbon dioxide	Gray	do	do	Do.
Inert gases:				
Argon, oil pumped	do	do	White	Gray
Argon, water pumped	do	do	Gray	Do.
Carbon dioxide	do	Gray	do	Do.
Helium, oil pumped	do	Orange	do	Do.
Helium, oil free	Buff	Gray	do	Do.
Nitrogen, oil pumped	Gray	Black	Gray	Do.
Nitrogen, water pumped	do	do	Black	Do.
Fire fighting gases:				
Carbon dioxide	Red	Red	Red	Red
Methyl bromide	do	Brown	do	Do.

The use of color coding for compressed-gas cylinders is mandatory. The assignment of colors to compressed-gas cylinders is made only after approval of the Standardization Division, Office of the Assistant Secretary of Defense (Supply and Logistics). Cylinders which have a background color of yellow, orange, or buff shall have the title painted in black. Cylinders which have a background color of red, brown, black, blue, gray, or green shall have the title painted in white.

Gas Cylinder Valves

Valves designed to control the flow of compressed gases are forged of brass, bronze, or steel, and are made in various shapes and sizes. Figure 14–3 and 14–4 illustrate typical types. The valves are opened and closed with either hand-operated or wrench-operated spindles. When the valves are opened, gas flows through a threaded male cylinder connection into the valve body, and past the valve outlet connection into the pressure regulator.

To prevent leakage of gas above the valve stem when

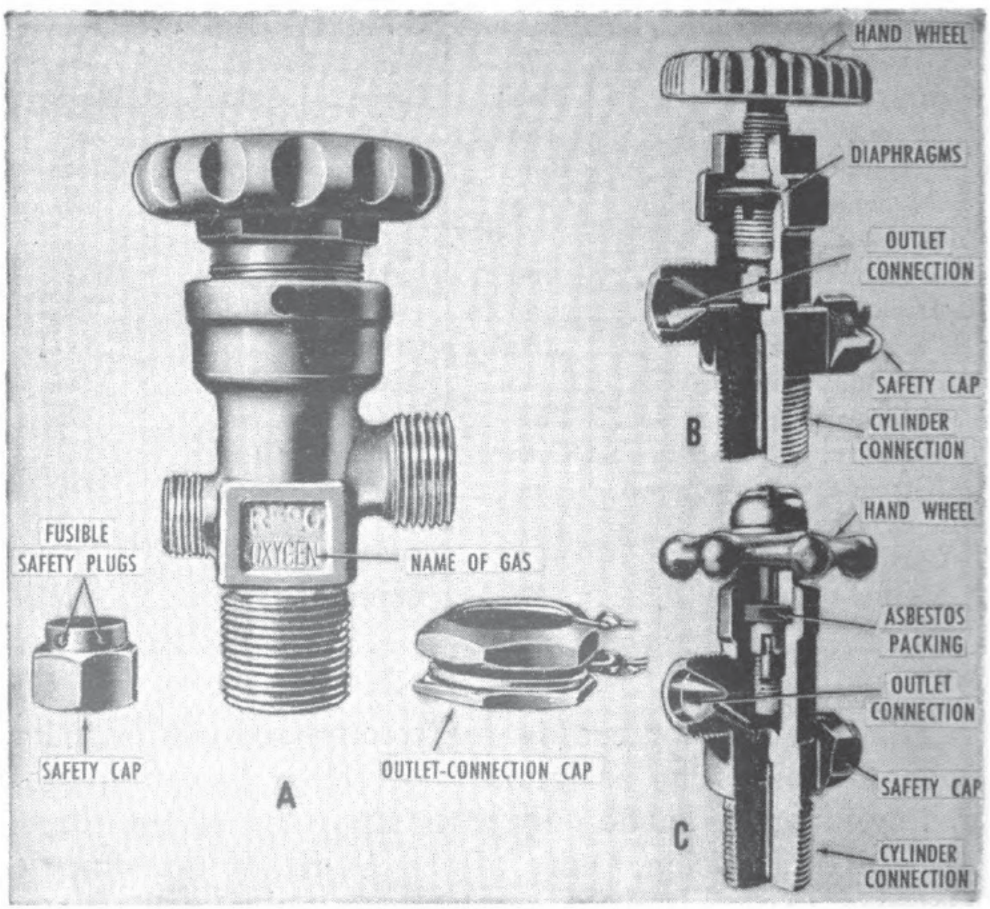


Figure 14–3.—Oxygen cylinder gas valves: (A) external view of one type valve, with related safety and outlet-connection caps; (B) cutaway view of same valve, showing diaphragms to prevent gas leakage when valve is opened; (C) cutaway view of another type valve, with asbestos packing to prevent gas leakage when valve is opened.

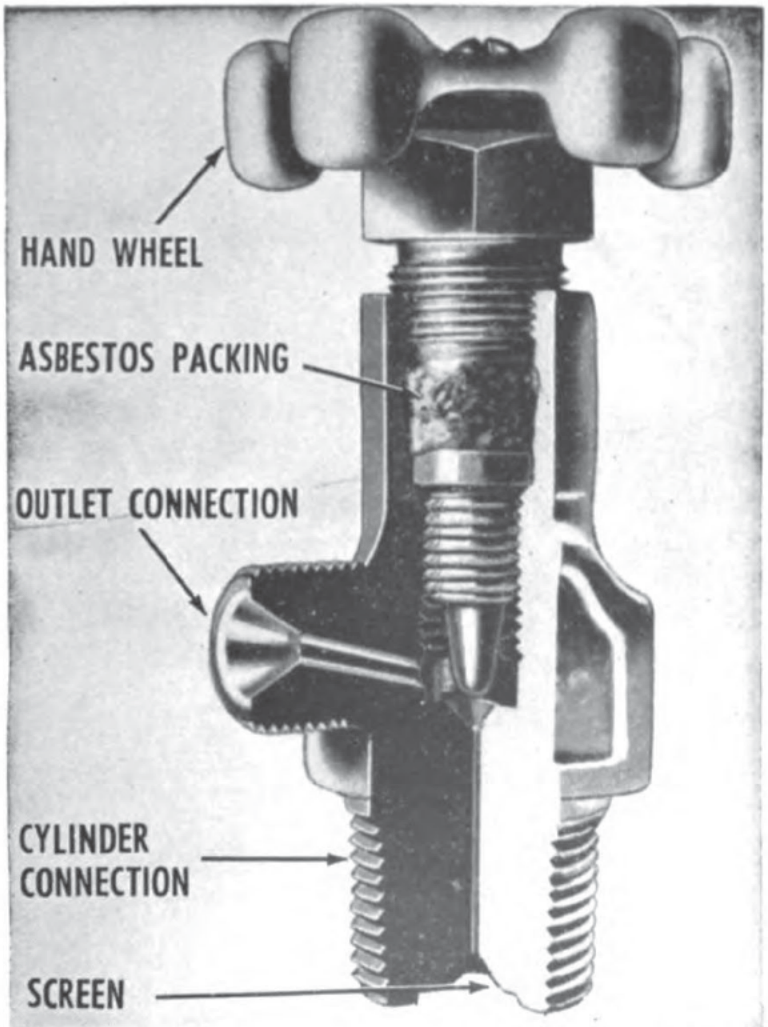


Figure 14–4.—Cutaway view of an acetylene-cylinder valve, showing asbestos packing. (Some valves have wrench-operated spindles instead of hand wheels.)

the valve is opened, each valve is equipped with asbestos, leather, or rubber packing or metal diaphragms. The majority of the valves have safety devices. (For acetylene and ammonia the safety devices are in the cylinders rather than in the valves.) The safety devices consist of fusible metal plugs, or rupture discs, or both. For some gases spring loaded safety valves are used. If the pressure becomes excessive when exposed to heat, the fuse plugs melt and the discs burst, to release the contents of the cylinder. Acetylene valves have screens in the cylinder connections;

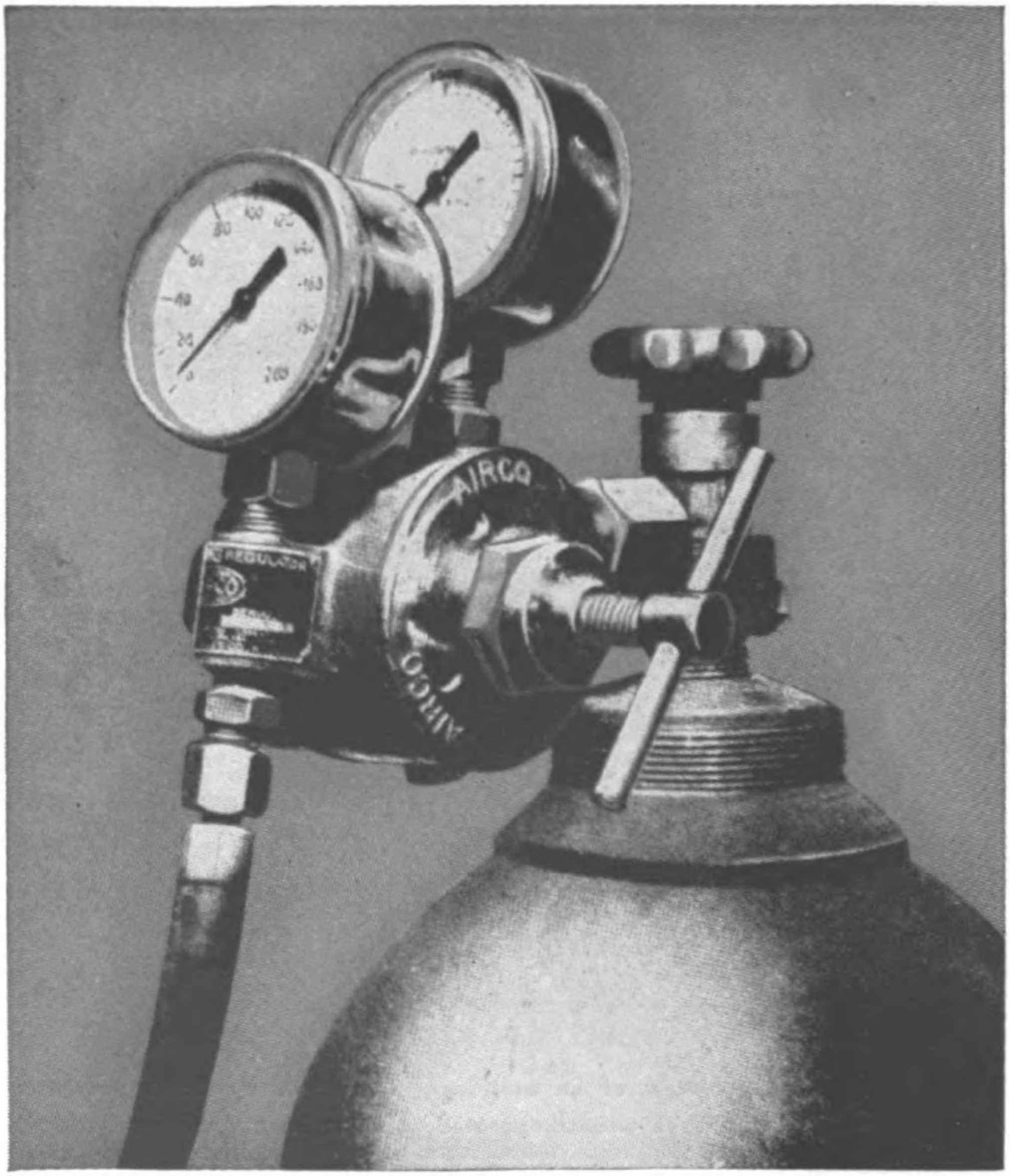


Figure 14–5.—Gas pressure regulator attached to the valve of an oxygen cylinder.

other valves have none. The name of the gas for which the valve is intended is stamped on the body of the valve (fig. 14–4). Valves are not interchangeable.

Gas Pressure Regulators

Pressure regulators (fig. 14–5) reduce the pressure of compressed gases from cylinder pressure to the desired

working pressure. All regulators are marked with the name of the gas for which they are intended.

TYPICAL GAS GENERATING PLANT (CO_2)

Having discussed the nature and uses of various compressed gases employed by the Navy, the next step is to become acquainted with the construction and operation of gas generating plants. Since there is a basic similarity in the plants used for the several different gases, the study of one typical plant, such as the portable carbon dioxide (CO_2) plant, will give you a general understanding of the generating process.

Methods of Production

Carbon dioxide is a heavy, colorless gas which regularly constitutes a very small proportion (about 0.03 percent) of the earth's atmosphere. It is also often found in spring water, in volcanic gases, and in certain minerals. The gas is generated by various natural processes, including ordinary fermentation, the decomposition of carbonates by heat or by mineral acids, the combustion of materials containing carbon, and the breathing (exhaling) of men and animals.

Various industrial methods may be employed for the production of liquid carbon dioxide, but the process used in the portable plant divides the process into the following three general phases:

1. Fuel oil is first burned, to permit carbon in the oil to combine with oxygen in the air and thus form carbon dioxide along with other combustion gases.
2. Carbon dioxide is then separated from the other gases of combustion by permitting a special chemical solution to absorb the CO_2 from the combustion gases and then, when heated, to again release the gas.
3. Released CO_2 gas is then liquefied by a process involving repeated steps of cooling, purifying, and compressing.

The Portable Plant

The plant consists of numerous parts, including drums, towers, vessels, pumps, blowers, motors, compressor, and various other units, designed and connected to produce liquid carbon dioxide from ordinary diesel fuel oil by what is known as the Girbotol process. A central electrical panel is provided for control of the electric motors; the flow of gases and liquids through the pipe lines is controlled by means of numerous valves; and various temperature and pressure gages and other miscellaneous instruments provided for a control of the processing itself. The entire plant is installed in a commercial van-type semitrailer, so that it can be easily moved to any convenient location.

In addition to a supply of about 65 gallons of diesel fuel oil for every 8 hours of operation, the plant requires a constant source of about 50 KW, of 220-volt 3-phase alternating current, and an adequate supply of water for cooling. Necessary chemicals furnished with the plant also must be replenished from time to time. With these supplies, the plant is capable of producing liquid carbon dioxide at the rate of 150 pounds (three 50-lb cylinders) per hour, or 3600 pounds in 24 hours of continuous operation.

Generating Process in Brief

Generation of the CO_2 starts with the carrying of diesel fuel oil and air to a furnace, in which the mixture is burned. This combustion produces flue gases, of which CO_2 constitutes about 15 percent. These gases are then cooled by being passed through a spray of sodium carbonate (Na_2CO_3) solution, which also serves to remove any sulphur dioxide (SO_2) which might be present. The cooled gases are then brought into intimate contact with a solution of monoethanolamine (MEA) which at temperatures of 80° to 120° F has the property of absorbing the carbon dioxide. The remaining unwanted flue gases are vented to the atmosphere.

In another container, the CO_2 is released by the MEA solution, at a temperature between 290° and 300° F. The raw CO_2 is then cooled, and the water and MEA vapor removed from it. The CO_2 is then successively cleaned, chilled, compressed and cooled in two stages, filtered, dried, compressed and cooled again until it is liquefied. The liquid CO_2 is accumulated in a surge drum, or it may be piped into a cardox auxiliary storage and refrigeration unit. From either the surge drum or the cardox unit, the liquid CO_2 is transferred into steel cylinders or bottles in quantities of 50 pounds each. These cylinders are then transported to the point of ultimate use.

Operating and Maintaining the Plant

The CO_2 plant can produce up to its rated capacity only as long as it is accurately adjusted for efficient operation. These adjustments are fully discussed in related manufacturer's instruction books. To determine what adjustments must be made, the various gases and chemicals involved in the generating process must be continuously analyzed. These analyses and subsequent plant adjustments must be accurate. Maintenance of the plant consists of proper lubrication and the repair or replacement of worn or damaged parts.

The MMG who is responsible for operating gas generating equipment, refilling gas cylinders, making gas analyses, and standing watch on gas generating equipment must be familiar with the Navy training course, *Field Manufacture of Industrial Gases,* NavPers 10078.

GENERAL PRECAUTIONS IN HANDLING GASES

It must be remembered constantly that all compressed gases are hazardous. Many detailed precautions could be set down with regard to the generating, handling, using, storing, and transporting of these gases. The more important precautions are summarized in the following paragraphs:

In PRODUCTION OF THE GASES, make certain that all

special precautions relative to the particular gas are observed.

1. See that all required gas or chemical analyses are carefully made and recorded.
2. Make certain that all plant adjustments are made in accordance with these analyses.
3. Constantly inspect for leaks and remedy immediately any leaks located.
4. Watch all pressure and temperature gages with extreme care.
5. Never permit any flames, sparks, or flammable material in the plant.

In HANDLING THE COMPRESSED GASES, never use gas from a cylinder except through a pressure regulator, with its adjustment screw released.

1. Open the cylinders by hand, never with hammers or wrenches.
2. Crack open the valve ¼ turn and close, before connecting the pressure regulator; do not crack the valve near sparks or other sources of ignition.
3. Do not let gas enter pressure regulators suddenly.
4. Open valves full when cylinder is in use (only 1¼ turns for acetylene valves).
5. Never tamper with safety devices; never force-fit any of the connections.
6. Close valves which leak at the stem; release gas to outdoor atmosphere if safety device leaks.
7. When referring to a particular gas always use its identifying name—never refer to it as just "gas."
8. Make sure hoses and fittings are always tight; do not interchange fittings or hoses with similar equipment for other gases.
9. Never tighten an adjustment nut to stop a leak before first closing the valve and allowing the gas to escape.
10. Close the valves and replace outlet caps when cylinders are not in use.

11. Before removing pressure regulators, close the valve and release all gas from the regulator.

In HANDLING THE GAS CYLINDERS, use the cylinders only for the gas for which they are intended.

1. Never remove numbers or any other markings from cylinders.
2. Do not use cylinders for rollers or any other nonstandard purpose.
3. Never handle cylinders roughly or use them where they can be damaged by falling objects, etc.; always handle all cylinders as though full (unknown pressure remaining may otherwise cause accidents).
4. Do not lift cylinders by valve caps but provide carrying devices—never drag or slide.
5. To promote more rapid discharge, never immerse more than 20 percent of the cylinder surface area, and never immerse in water over 125° F (fusible plugs will otherwise soften or melt).
6. Never store near flammable material (oil, gasoline, waste, etc.), in damp locations, near live wires, near corrosive chemicals or fumes, near heaters, or near any other gas.
7. Erect fire-resistant partitions between flammable and nonflammable gases.
8. Store liquid gases (except ammonia) upright.
9. Make sure storage rooms are ventilated to prevent accumulation of an explosive or otherwise harmful concentration of gas.
10. Mark empty cylinders "empty" or "MT," and segregate them from full cylinders.

QUIZ

1. The hold of a ship is suspected of being filled with some gas. A shipmate suggests that you lower a lighted candle into the hold. He says that if the candle goes out it means CO_2 is present; if the candle flares up brightly then oxygen is present. Is he correct?
2. Which of the following gases are flammable?
   a. Aerosol.
   b. Ammonia.
   c. Argon.
   d. Carboxide.
   e. Chlorine.
   f. Ethyl chloride.
   g. Ethylene oxide.
   h. Freon.
   i. Hydrogen.
   j. Propane.
   k. Methyl chloride.
   l. Nitrogen.
   m. Nitrous oxide.
3. Why must acetylene never be pressurized above 15 psi?
4. Carbon dioxide is not poisonous. Why then is it considered a dangerous asphyxiant?
5. What is the purpose of the freon used in aerosol bombs?
6. While waiting for the medical officer, what is one sure first-aid measure to take with any man who has been overcome by breathing any of the gases listed in this chapter?
7. Is nitrogen completely inert?
8. What are the principal industrial gases that Machinist's Mates are expected to handle?
9. What does Boyle's gas law state?
10. What is the latent heat of condensation?
11. How may leaks be located in acetylene equipment?
12. Which gas cylinders have recessed or only slightly rounded tops?
13. What gas is identified by a green cylinder with one white stripe? By a completely orange cylinder?
14. What is the "Girbotol process" used for?

CHAPTER 15

WATCHES AND CASUALTY CONTROL

The operation of engineering plants becomes unreliable when machinery derangements are of frequent occurrence. Certain types of derangements may be caused by radical maneuvering of a ship or prolonged operations at high speeds. For the most part, however, malfunctioning of engineering machinery reflects inadequate training of engineering personnel, improper and inattentive watch standing, and improper preventive maintenance.

This chapter is intended to stress attentive and accurate watch standing in addition to stressing preventive maintenance. Preventive maintenance pays dividends—it means that you will spend less time tearing down equipment for overhaul; it may even save your life. In addition, preventive maintenance saves MONEY—it's your money and you can do something about it. Learn all you can about your job and do that job to the best of your ability.

ON WATCH

From midwatch to evening watch your duties as a Machinist's Mate are extremely important to the welfare of the ship and crew. Whatever the duty watch, you, as a Machinist's Mate, are responsible for knowing the status of every piece of machinery at your station, for promptly handling any necessary change in speed or setup, and for recording correctly all data concerning the operation and maintenance of the machinery. You must be sure that the

log is up to date, that the status boards are correct, that you know what machinery is operating, and that you know what the night orders are before you relieve the watch. Reporting the watch relieved means to the Chief that you know what the score is and have the situation under control. DON'T TRY TO RELIEVE THE WATCH FIRST AND FIND OUT THE SCORE LATER.

Your duties while on watch include not only the proper operation, care, and emergency repair of machinery in your charge, but also the recording of pertinent data on standard or ship forms provided for the purpose. It is essential, therefore, that you know what logs and records are kept, how to take the readings, when to take readings, and what should be immediately entered on the bell sheet or reported to the OOW for recording in his log.

DUTIES OF THE WATCH

The duties of the various watches summarized in the following paragraphs will vary in accordance with the size and type of ship, the layout of the ship, and the type of machinery installed. In general, however, the duty summaries are applicable to all steam-driven naval vessels.

In general, Machinist's Mates stand watches at the main engine throttle, at telephones, on miscellaneous engineroom machinery, on pumps and condensers, on compressors, on evaporators, on refrigeration machinery, in the steering engine room, and in repair parties. Wherever you are on watch, you must know how to set various conditions of material readiness, and how to arrange split plant and cross connected operations at your station. Before standing any watch in the machinery spaces, familiarize yourself with the posted operating instructions and safety precautions for the particular pieces of machinery and equipment at your watch station.

Main Engine Throttle Watch

Being a throttleman at the main engines is a very important task. Orders from the bridge relative to movement

of the propellers must be complied with immediately. To make correct adjustments for the required speed you have to keep a close watch on the rpm indicator on the throttle board, and open and close the throttle as required to attain or maintain the necessary rpm. In addition to handling the throttle itself, you may also have to operate various associated valves, accurately log all speed changes in the Engineer's Bell Book, visually check all gages

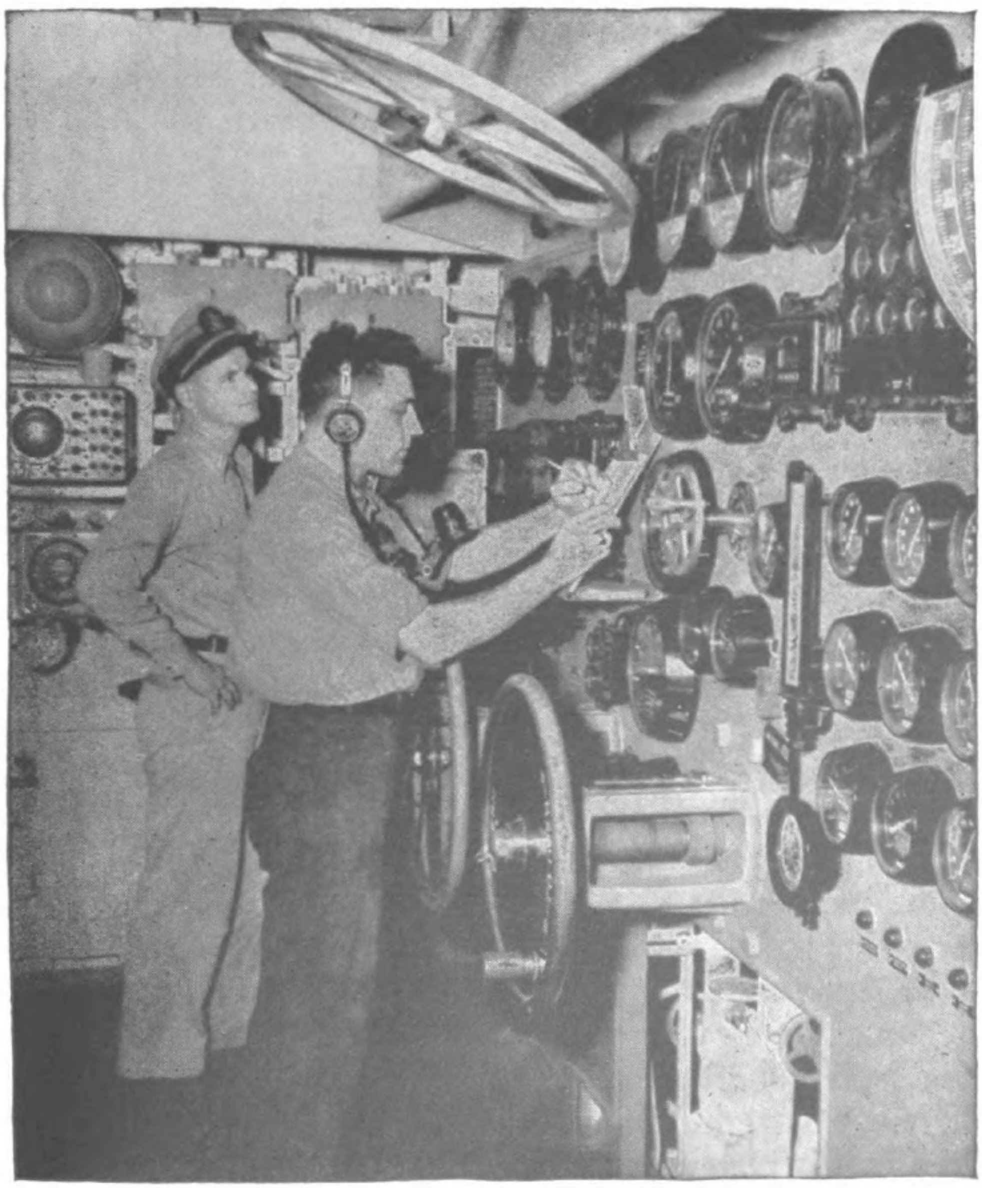


Figure 15–1.—Standing watch at the main engine throttles.

(pressure, temperature, vacuum, etc.) installed on the throttle board, and keep the MMC informed of any abnormal gage readings. (See figure 15–1.)

This duty requires a thorough knowledge of throttle valve operating procedures and their use in conjunction with steam pressure and temperature, and ship's speed; a thorough knowledge of correct readings for throttle board gages, to detect instantly any abnormality; a knowledge of acceleration and deceleration tables; advanced knowledge of safety precautions pertaining to the main engines and associated auxiliaries and steps to be taken in cases of material casualty; and a general knowledge of fireroom operation insofar as they concern the engineroom operation.

JV Phone Talker

If you are assigned to man one of the phones on the JV communication circuits in the engineering spaces, you must have a knowledge of engineering terms and standard sound powered telephone procedure. The JV communications circuits connect the enginerooms with the bridge, repair parties, after steering engineroom, firerooms, emergency diesel generator rooms, air compressor room, evaporator room, and any other vital machinery or central space of the ship. As a phone talker you must remain alert at all times and take special care to repeat verbatim any messages received or to be transmitted.

Upper-Level Engineroom Watch

If you are assigned to the upper level watch in the engineroom (fig. 15–2), you will usually be responsible for recording periodic temperature and pressure readings from the various gages on, or connected to, the upper-level machinery; for making required valve adjustments to correct conditions indicated by slight variations from the normal readings, and reporting unusual conditions to the Chief in charge; for maintaining a normal water level in the deaerating tank, if it is in the engineroom, by ad-

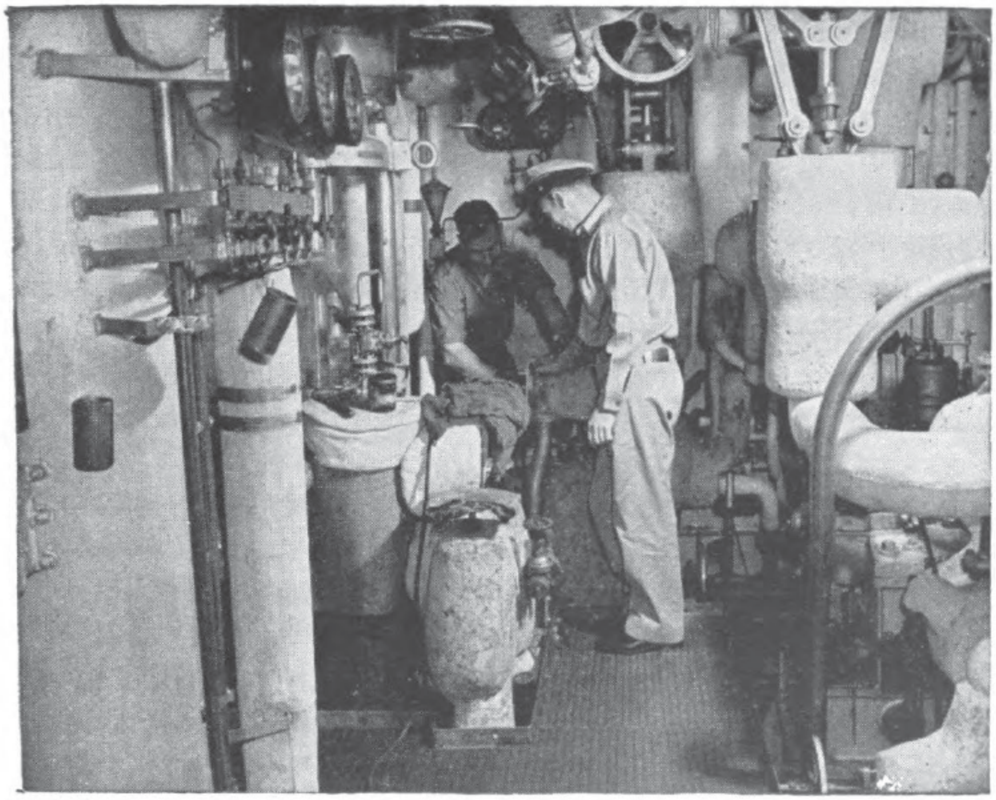


Figure 15–2.—Duty on the upper level of an engineroom.

justments of the excess and make-up feed valves; for starting and securing turbogenerators, and other upper-level machinery, as ordered; and for maintaining an adequate gland seal pressure on the turbogenerator.

You must be skilled in detecting unusual noises, vibrations, or odors which may indicate faulty machinery operation, as well as in taking appropriate and prompt corrective measures. You must be skilled in reading and interpreting measuring instruments. You must be ready, in emergencies, to act quickly and independently. The record with which you will be concerned on this duty is the Main Engine Operating Record.

Lower Level Watches

If you are assigned as pump man to the lower level of the engineroom, you will be responsible for starting, operating, and stopping equipment such as main lube oil

pumps and lube oil coolers, main condensate pumps and main condenser; and if installed in the engineroom, the feed booster pumps, fire pumps, and air compressors; and for keeping vital standby pumps or equipment in readiness for instant use.

The engineroom lower level watchers include the oiler, the lube oil watch, the condensate and condenser watch, and the fire pump and booster pump watches. On some ships, because of limited space and/or personnel, watch standers may be responsible for standing watch on two pieces of equipment.

An OILER, in addition to complying with the posted instructions and safety precautions for the machinery and equipment at his station, usually performs the following duties:

1. Regulates the cooling water flow through the main lube oil cooler to maintain the correct outlet temperature.
2. Checks the level of the oil in the reduction gear sump.
3. Operates the oil purifier.
4. Checks bearing temperatures, i.e., main thrust bearing.
5. Checks the system for leaks.
6. Cleans the lube oil strainers during each watch.
7. Checks the pressures in the lube oil system.
8. Supervises the lube oil pump man; sees that the standby lube oil pump is ready for instant use or for automatic start up.
9. Performs any other additional duties which may be assigned.

A LUBE OIL PUMP WATCH STANDER, in addition to complying with the posted instructions and safety precautions for the machinery and equipment at his station, usually performs the following duties:

1. Starts, operates, and secures the main lube oil pumps. This duty includes (a) adjusting the pump governor to maintain the correct discharge pres-

sure; (b) checking the pump bearings and packing glands for signs of overheating; (c) regulating the flow of cooling water to the pump lube oil cooler to maintain correct bearing temperature; (d) checking the lube oil level in the pump, and adding oil when needed—replenishing oil in the gravity oil feed sumps where installed; and (e) inspecting the pump glands and lube oil suction and discharge piping for leaks.

2. Shifts the lube oil pumps at designated times.
3. Strikes down oil to the main sump when required.
4. Performs any other additional duties which may be assigned.

As a CONDENSATE PUMP AND CONDENSER WATCH STANDER (the fire pump and booster pump watch might be combined with this watch), usually handled by two MM's, you will perform duties similar to the lube oil pump watch stander with the following additional duties:

1. Check the exhaust trunk and injection overboard temperature.
2. Keep the condenser properly vented to prevent the condenser from becoming air bound.
3. Keep the gage glass on the condenser hotwell under constant observation—watch the condensate level.
4. Start and secure additional pumps as required to keep the condensate level at the correct height.
5. Perform any other additional duties which may be assigned.

Shaft Alley Watch

Another main engine duty to which you may be assigned is that of keeping watch on the bearings of the propeller shafts leading from the reduction gears (or motors of a turboelectric driven ship) to the ship's propellers. The duties of the SHAFT ALLEY WATCH STANDER are as follows:

1. Checks all spring bearings for proper lubrication, including correct oil level, condition of the oil,

proper operation of self-oiling devices (ring or chain), and bearing temperature.

2. Checks and adjusts stern tube gland for correct amount of leak-off.
3. Responsible for having the shaft alley bilge pumped.
4. Be especially alert during high speed to observe any abnormal rise in bearing temperature.
5. Reports hourly, by phone, to the control engineroom and at any time if abnormal conditions develop.
6. In case of ships which have the main thrust bearing in the shaft alley, the shaft alley watch stander is responsible for operation of the main thrust bearing lube oil system.
7. Performs any other additional duties which may be assigned.

Repair Party Machinery Repair Duty

As a Machinist's Mate 3, you will probably be a member of a repair party in your ship's damage and casualty control organization. As such, you will have special machinery repair duties during General Quarters, damage control drills, or emergencies. Under direction of the petty officer in charge of the party, you may be made responsible for making correct casualty control setups for vital systems; for knowing the split-plant and system-segregation setup.

You may be responsible for making repairs to steam and oil lines, or, if repairs are impossible, for seeing to it that stop valves on these lines are closed to secure damaged sections of the plants; for fighting fires; for setting material readiness conditions; for controlling flooding in the event of underwater damage; for shoring and repairing bulkheads, clearing wreckage, using the acetylene torch, etc.; or for making prompt and accurate analyses of casualties, especially in engineering spaces, and improvising rapid repairs.

For these general repair party duties you must have a thorough knowledge of the fuel, steam, water, drainage,

and lubrication systems on your ship, including the location of all stops, bypass valves, and remote controls. You must know the general operation of all engineering installations well enough to assist in making emergency repairs. You must have a practical knowledge of all fire fighting and other damage control techniques. You must know the location and function of various doors, hatches, fittings, etc., which contribute to the watertight integrity in your assigned section of the ship.

You must know how to use rescue-breathing apparatus and other specialized tools and equipment employed in damage control repairing. You must know the use of protective clothing, and how to give first-aid to casualties of fire, shellfire, demolition, shock, or contaminated atmosphere. For the welfare of yourself, your shipmates, and your ship, you should be resourceful and ingenious in performing the various tasks concerned.

WATCH, QUARTER, AND STATION BILLS

Each division officer prepares a Watch, Quarter, and Station Bill for his division. You will generally find the following information on this bill:

1. Organization of the division (i.e., sections and watches).
2. Listing of each man as to billet number, locker number, bunk number, compartment number, name, rating, and rate (actual and allowance).
3. Watch assignments for each man under various conditions of battle readiness.
4. Station each man will have and what he will provide for emergency situations such as Fire, Rescue and Assistance, General Emergency, and any other condition which may be listed for your ship.
5. Additional boarding and salvage party, scuttle ship party, landing force, special sea detail, and other special duties and stations which each man may have.

This Watch, Quarter, and Station Bill tells you where you fit into the engineering picture. Check it frequently, for it is your duty to know where you belong under all conditions. There is NO EXCUSE FOR NOT KNOWING. The bills may be differently designed for different ships, but the stations and duties are always approximately the same.

LEGAL ENGINEERING RECORDS

Of the numerous records and reports compiled by the engineering department of your ship, only the Engineering Log and the Engineer's Bell Book are official legal records. That is, they may be used in any military or civilian court as final proof of any action taken on or by the ship, and as evidence for or against any officer or enlisted man of the ship's crew who may be brought before the court or naval board.

Engineering Log

The Engineering Log, NavShips 117, is an official midnight-to-midnight daily journal of the ship's engineering department. It is an account of the operation of all engineering machinery and of all activities of importance that take place daily in the engineering spaces.

The original draft of the Engineering Log (written in longhand) constitutes the official legal record. No erasures are to be made in the remarks; any errors occurring should be overlined, initialed and, if practicable, the correct entry made immediately following the entry struck out. While the ship is under way, the log is kept in the control engineroom; when in port, the log is kept in the live engineroom or the engineering office, if one is provided. On smaller naval vessels the log is generally filled out by the Machinist's Mate of the watch or the one having the day's duty. On the larger ships, the engineering log is maintained by the engineering duty officer. The log is signed by the engineer officer of the

watch or the engineering duty officer before he goes off duty; by the engineer officer each day; and by the commanding officer at the end of each month.

Information required on the Engineering Log can be divided into two groups. The front page of the log contains three tables. Hourly entries in Table 1 indicate the average rpm for all shafts and the speed in knots. Table 2 requires entries for lube oil, fuel oil, and water (all in gallons). Table 3 requires information on the ship's draft. The bottom of the front page has space for time zone information.

Under "REMARKS," which includes the lower part of the front page and the entire back page of the Engineering Log, entries such as the following should be made:

1. Major speed changes, such as "one-third," "standard," and "full."
2. New standard speeds (if such were initiated) and the time that the speed changes were made.
3. Engine combinations in use.
4. Boilers in use.
5. Any special entries required by the *Bureau of Ships Manual* or letters from the Bureau of Ships.
6. Record of casualties to personnel or material in the engineering department.
7. Remarks of the engineer officer of the watch or day.

The "REMARKS" SECTION of the log must be written up neatly, legibly, in complete sentences, and with the use of standard phraseology. Watches are headed 00-04, 04-08, 08-12, or 12-16 (or the watches may be 8 hours in length). No other form is to be used. The midwatch is required to enter the complete status of the engineering plant, including boilers in use and the fuel-oil tanks supplying them, auxiliary machinery in use, generators in use, make-up feed tanks in use, and the standby fuel-oil suction and make-up feed tanks. Any change in the status of any piece of machinery or tank is also entered in the log.

Engineer's Bell Book

The Engineer's Bell Book, is an official legal record kept of the time any bell, signal, telegraph, or other form of order regarding change in the movement of the propellers is received at the control station of the main engines; the interpretation of each order; the actual propeller rpm ordered, and the counter reading at the time the order is given.

The RPM ENTRY for any signal indicates the rpm RESULTING FROM THE ACTION TAKEN—not necessarily the rpm which has been ordered. Sometimes the signals are given in such rapid succession that there is not time to reach the rpm for one signal before the next signal is received. IN SUCH CASES, THE RPM BEING MADE AT THE TIME THE NEXT SIGNAL IS GIVEN IS RECORDED. At all other times the ordered rpm is entered at the time the required rpm is achieved. A COUNTER READING is taken for each signal, and for every hour on the hour.

Each engine has a bell book at the engine control. Where one or more shafts are controlled from a throttle station, a single sheet is used for each station. A new sheet is started for each day and as many sheets are used as are necessary. The original entries must remain without erasures. Errors must be overlined, initialed, and corrected with the proper entry in the space below. The entries are generally made by the throttleman; when entering or leaving port, or during any other maneuvering activity, however, the entries are made by an assistant to the throttleman. At the end of a watch, the engineer officer of the watch or the senior petty officer of the watch, signs his name after the last entry. The next watch continues on the following line. By 0830 of each day, the record is turned into the log room with the other logs.

Disposition of the Legal Records

Both the Engineering Log and the Engineer's Bell Book sheets must be preserved as PERMANENT RECORDS ON BOARD for a period of three years, except in compli-

ance with a demand from a naval court or board or from the Navy Department. In the latter case copies, preferably photostats, of such sheets as are to be sent away from the ship, must be prepared for the ship's files and certified as true copies by the engineer officer. The record sheets may be disposed of three years after date of the last entry, in accordance with current instructions. Should a vessel be placed in inactive status, the current books (under three years old at time of inactivation) must be retained. If a vessel is decommissioned for disposal or scrap, the current books are forwarded to the nearest Naval Records Management Center.

ENGINEERING OPERATION RECORDS

There are a number of engineering operation records with which you will have some concern, depending upon the watches to which you may be assigned. These records include the Main Engine Operating Record, the Engineer's Night Steaming Orders, the Distilling Plant Operating Record, the Air Compressor Operating Record, the Refrigeration Operating Record, the Air Conditioning Operating Record, the Boat Operating Record, and the Lighting-Off and Securing Check-Off Sheets.

Main Engine Operating Record

The Main Engine Operating Record is one of the most important records of the ship. By means of this record the engineer officer can determine how the main engines are being operated. This means, also, that the efficiency of yourself and your Chief can be closely evaluated while you are on the engineroom duty watch. You must, of course, make correct entries, regardless of what inefficiency they may reflect. And remember that it is from the data contained in this record that the officer of the watch prepares the all-important Engineering Log. One record sheet (NavShips 3652) is prepared for each main engine—a four-engine ship would have four sheets prepared each day. Common entries (indicated with aster-

isks in following lists) are generally omitted on the sheets for all but one engine in the control engineroom.

The FRONT PAGE of the record is designed to include the following data (for each hour) and information (for each watch):

1. Instantaneous rpm (read on the revolution tachometer) and speeds in knots (determined from the speed curve chart—knots vs rpm) for the main shaft at the end of each hour.
2. Revolution counter reading and average shaft rpm for the hour at the end of each hour.
3. Total of counter readings and average hourly rpm for all shafts or engines at the end of each hour.*
4. Pressure (psi) and temperature (degrees F) of the main steam line at the end of each hour.
5. Steam pressures of the cruising turbine steam chest, first-stage, and exhaust; high-pressure turbine steam chest and various changes (as indicated); and low-pressure turbine inlet at the end of each hour.
6. Turbine rotor clearances for the cruising, high-pressure, and low-pressure turbines at the end of each hour.
7. Main condenser gage vacuum, absolute pressure, exhaust trunk temperature, injection temperature, and overboard discharge temperature each hour.
8. Main condensate pressure, temperature, and chloride content (epm) each hour.
9. Fuel oil allowed (found on fuel oil allowance sheet) and expended for all engines each hour and the hourly fuel score (allowance ÷ expenditure = score).*
10. Time zone information.
11. Remarks (in memorandum spaces) regarding operations throughout the first three 4-hour watch periods (0000-1200)—including information pertaining to inspections, casualties, repairs, lubrications, fueling cleanups, etc.

12. Signatures of the chief in charge (who checks the record for accuracy) and the engineering officer (who approves the record).

The BACK PAGE of the record is designed to include the following data and information:

1. Lube oil pressures of the lube oil pump discharge, to the pump governor, to the turbine bearings, and to the reduction gears at each hour.
2. Temperature of the lube oil to the lube oil cooler, from the cooler, in the hottest shaft journal bearing, and in the hottest thrust bearing at each hour.
3. Level of lube oil in main pump at each hour.
4. Steam pressures of the auxiliary and the auxiliary exhaust steam lines at each hour.*
5. Steam chest pressure of the main circulating pump at each hour; steam chest pressure and discharge pressures of the main condensate pump or condensate booster pump at each hour.
6. Steam chest and discharge pressures for each main feed pump, main feed booster pump, and cruising feed pump; and the rpm for each main feed pump at each hour.
7. Temperature of the air ejector discharge and the feed heater discharge of the feed-water system at each hour, a check signifying operation of feed heater drain booster pump.
8. Water pressures of the fire main and the salt-water cooling system at each hour.
9. Checks signifying hourly inspection of all line shaft and stern tube bearings.*
10. Quantity, temperature, and salinity of feed water in the feed tank at the end of each hour.*
11. Time zone description information.
12. Remarks (in memorandum spaces) regarding operations throughout the last three 4-hour watch periods (1200-2400) of the day.

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* Generally listed only on the sheets for one engine in control engineroom.

Engineer's Night Steaming Orders

Each evening when the ship is underway, the engineer officer makes out the Engineering Department Night Steaming Orders which are delivered to the officer of the watch. These orders become effective as soon as they are received. The forms used will vary for each ship, but the contents will be similar in all cases. The officer of each watch of the night will initial the orders, and at 0800 the orders will be picked up with the other records.

The orders will usually indicate the standard speed in knots and rpm; boilers to be in use; steam pressure and temperature; forced draft blowers to be in use; operating, standby, and emergency fuel-oil tanks to be used, and the extent to which they should be filled; sprayer plates; make-up, standby, and emergency feed-water suction lines; and such special instructions as the engineer officer deems necessary (e. g., shifting of tanks, line pressures, blowing of tubes, etc.).

Air Compressor Operating Record

The Air Compressor Operating Record maintained by the man on the air compressor watch, requires the following data:

1. Temperatures of the air inlet and discharge of each stage, and of the final air discharge of the compressor in operation.
2. Air pressures of each stage of the final discharge of each compressor.
3. Cooling water pressure and inlet and outlet temperatures for each compressor.
4. Lube-oil pressure and temperature for each compressor.
5. Time each compressor was started, stopped, and operated.
6. Remarks concerning the operation and maintenance of all compressors for each watch.

Lighting-Off and Securing Check-Off Sheets

The Lighting-Off Check-Off Sheet and the Securing Check-Off Sheet for each ship differ in accordance with the procedures developed by the engineer officer. These sheets contain step-by-step checkoff procedures for starting and securing the main engineering plant and associated auxiliaries. The OOW will sign these sheets.

ENGINEERING MAINTENANCE RECORDS

A very important group of engineering records with which you will be concerned is that of the maintenance records. This group includes the various periodic checkoff lists, work books, and the zinc charts. The checkoff sheets comprise numerous daily, weekly, monthly, quarterly, and other tests and inspections. These checks must be made to ensure that the various engineering plants and auxiliary equipment are always kept in first-rate operating condition. The purpose of the checkoff lists is to ensure that no item of equipment is overlooked or any test forgotten. Several other records of interest to you, because they concern the maintenance and repair of machinery you will work with, and which may be dependent upon information furnished by you, include those comprising the over-all Material History and the Current Ships Maintenance Project.

Daily Check-Off Lists

The daily checkoff lists require that specific tests and/or inspections (which will concern Machinist's Mates) be made daily. A sample list might include the following items:

1. Jack over main turbines 1¼ turns with lube-oil pumps running.
2. Turn all idle auxiliary turbines by hand, and circulate oil by hand pump.
3. Run main air ejector one-half hour.
4. Inspect parts under vacuum for leaks (when steaming).

5. Test evaporator coil and shell relief valves manually.
6. Jack over air compressors manually.
7. Jack over all pumps by hand.
8. Drain water from bottom of lube oil settling tank.
9. Test for contamination of lube oil in reduction gears, and purify the oil in accordance with instructions in the *Bureau of Ships Manual.*
10. Vent water sides of refrigeration and air-conditioning condensers.
11. Check accessible refrigeration and air-conditioning system parts for proper operation, and check the entire system for any unusual noise or vibration. (A separate checkoff sheet lists each refrigeration or air-conditioning piece of equipment.)
12. Check emergency generator diesel engine (if a MM is so assigned) for proper operation, including fuel, control lube oil, cooling water, and air supply systems and equipment. (Specific items are listed on a separate checkoff sheet.)

Weekly Check-Off Lists

The weekly checkoff lists (similar to daily lists in format) require that such tests and/or inspections as the following (concerning Machinist's Mates) be made weekly:

1. Check all valves, cocks, and joints of steam, exhaust, and drain lines for tightness.
2. Operate manually the relief valves on all piping systems in your assigned spaces.
3. Operate all pumps by steam or motor power.
4. Lubricate all emergency control governors, and trip the overspeed trips by hand.
5. Operate and oil all valves of the main propulsion plant which are not in use.
6. Operate all air compressors by power.
7. Test refrigerating and air-conditioning systems for possible refrigerant leaks.

8. Operate all idle refrigerant compressors by power, and alternate the compressors.
9. Test overspeed and back pressure trips and relief valve settings on all turbogenerators.
10. Visually inspect exhaust trunk for corrosion, etc.
11. Inspect any additional auxiliary engineering equipment attended by Machinist's Mates, in accordance with inspections called for by individual checkoff lists.

Monthly Check-Off Lists

Monthly checkoff lists (similar to daily lists in format) require that such tests and/or inspections as the following (concerning Machinist's Mates) be made monthly:

1. Inspect lube-oil sump tanks.
2. Purify all lube oil.
3. Inspect and clean or renew all zincs installed in engineering equipment.
4. Move all valves not in frequent use, and test remote-operating gear to all valves.
5. Inspect and clean air filters and intake valves to all air compressors.

Quarterly Check-Off Lists

As required by the Bureau of Ships, a more complete test and inspection of certain items of equipment is conducted quarterly. The following items are included in these lists:

1. Inspect exhaust trunk and last few stages of low-pressure turbine through manhole plate to detect corrosion or other defects.
2. Sound all turbine hold-down bolts, ties, and chocks with hammer to detect signs of loosening.
3. Clean steam strainers on auxiliary turbines (more often than quarterly if cruising is extensive) to prevent foreign matter from entering turbines, and to ensure strainer integrity.
4. Remove turbine inspection plates and inspect for loose blades or shrouding, or presence of corrosion.

5. Inspect shoes of thrust bearings for condition of bearing surface and take clearances to ensure proper position of rotor.
6. Blow out thrust bearing with air after examination to prevent foreign matter remaining.
7. Check main bearings for clearance, condition of journal, and bearing surface to ensure correct radial clearance.
8. Visually inspect the reduction gears and main turbines via the inspection plates.
9. Inspect gland packing for wear to ensure that an efficient seal is maintained.
10. Remove reduction gear inspection plates and inspect gears and oil-spray nozzles to ensure that they are free of scale and that an even oil flow is maintained. (Gears should be jacked for one-half hour with lube oil at operating pressure.)
11. Overhaul all auxiliary throttle valves.
12. Test all engineering piping to full pressure.
13. Inspect water sides of main and auxiliary steam condensers to determine if cleaning is necessary.
14. Test and calibrate all gages.
15. Make general inspection of air compressors, including the testing of gages, valves, bearings, filters, intercoolers, air passages, cylinders, speed-limiting governors, overspeed trips, and electric load required for starting.
16. Inspect liquid end valves (stems, disks, seats, springs, etc.) and steam valve gear for wear, and check relief valve settings on all reciprocating pumps.
17. Check all centrifugal and rotary pumps by testing the overspeed and speed-limiting devices and all relief valves, cleaning the lubrication system, renewing the lube oil or grease, checking all foundation bolts and dowel pins, and checking the internal water-cooled bearings and shafting.

Other Check-Off Lists

In addition to the daily, weekly, monthly, and quarterly checkoff lists, you will also have to work with annual, semi-annual, and sometimes bimonthly checkoff lists. There also will be checkoff lists prepared by the engineer officer at irregular intervals. These lists will include whatever is deemed necessary to be inspected and/or tested throughout the engineering spaces.

Under Way Check-Off Lists

An under way checkoff sheet is also frequently prepared by the engineer officer to ensure that certain tests or checks are made in the enginerooms when under way. Accompanying most of the items listed may be references to related articles of information or instruction in the *Bureau of Ships Manual.* Space is provided for the items to be checked on each watch. Typical listings on these sheets are as follows:

1. Inspect stern tube glands frequently.
2. Test main condenser for salinity every 15 minutes and the auxiliary condenser every 30 minutes, while under way.
3. Test deaerating feed tank hourly for chloride (and for hardness, if necessary).
4. Inspect lube-oil flow through sight glass frequently.
5. Clean strainers on lube-oil systems before getting under way, and during each watch.
6. Inspect float gage on lube-oil sumps frequently.
7. Log amount of oil in sump drain tank at the end of each watch.
8. Frequently inspect bearings, oil lines, etc. for oil leaks; and the bilges for the presence of oil.
9. Operate the oil purifier each day until water is eliminated.
10. Test oil in all self-oiling bearings after each extended run, or after 10 days of intermittent service.
11. Note position of finger pieces and tell-tale indicators of each turbine frequently each watch.

12. Read all gages frequently each watch.
13. Clean bilge suction strainers during each watch.
14. Inspect bearings for overheating, frequently each watch.

Work Books

Located in a convenient spot of each engineering machinery space on the ship is a note book (generally looseleaf) of machinery histories for units installed in the area. The PURPOSE OF THESE WORK BOOKS is to keep an accurate on-the-spot, chronological record of what should be formally entered on Machinery History Cards in the log room. The work books are turned in to the log room each week. After the entries have been made on the smooth record cards, the work books are returned to their respective areas. The Machinery History Cards are a part of a group of records known as the ship's Material History.

ENTRIES IN THE WORKBOOK should be a record of all repairs made and parts renewed on each piece of machinery, along with the date of repairs and the name of the man making them. The idea is to make the entries brief, but complete. List only the facts which are essential for future knowledge of work done on the machine. Do not take up space to tell how the work was done, what you are in the process of overhauling, the parts used, or other nonhistorical information.

For further discussion of machinery history cards and workbooks, refer to training courses for higher MM ratings.

ENGINEERING CASUALTY CONTROL

Engineering casualty control is concerned with the prevention, minimization, and correction of the effects of operational and battle casualties to engineroom machinery, related machinery outside of engineroom spaces, and the piping installations relative to the various pieces of machinery. The mission of engineering department personnel is the maintenance of all engineering services

in a state of maximum reliability under all conditions. Failure to provide all normal services will affect a ship's ability to function effectively as a fighting unit, either directly by reducing its military function, or indirectly by reducing habitability and efficiency.

Work involved in the HANDLING OF ENGINEERING CASUALTIES can be divided into three general phases:

1. Immediate action to prevent further damage.
2. Emergency restoration of service(s) interrupted by the casualty.
3. Repairs which completely restore damaged machinery, plants, or systems to their original condition.

To perform your casualty control job well, you must master the operation of the equipment at your normal duty station and at your battle station. Otherwise, you will be completely lost during an emergency. The Engineering Operation and Casualty Control Manual, your ship's Damage Control Book, the Ship's Organization Book, the manufacturer's emergency instructions for the equipment or systems on your GENERAL QUARTERS STATION, and the ship's Damage Control Bills are your primary sources of instruction for handling any engineering casualty in addition to maintaining the over-all damage resistance of your ship. These publications may vary on different ships, but in all instances they present the organization and procedures to be followed in event of engineering casualties, damage to the ship, or other emergency conditions.

REPAIRING MACHINERY CASUALTIES

When machinery casualties occur, you must know what procedure to follow in making the necessary emergency repairs. Not only must you know how to make the repairs, but you must also know how to notify responsible personnel of both the conditions and the action being taken. A procedure somewhat like that listed below should be adhered to in the engineering plant.

Securing for Repair

1. Immediately secure damaged sections or units, and contact the officer of the watch (if ship is under way) with regard to the condition existing and the action taken. Notify the engineer duty officer, if ship is at anchor.
2. Obtain permission from your MMC, engineer duty officer, or OOW for whatever further action is necessary.
3. Notify all spaces which will be affected by the secured services.
4. Wire or lock and tag all valves or machinery units being secured. This will protect the repair party. Be sure that associated remote operating controls are made inoperative and tagged. Tags should bear suitable instructions, such as DO NOT OPEN, together with the name and rate of the man in charge of the repair job.

Cutting-in After Repairs

1. Notify your MMC, engineer duty officer, or OOW that repairs have been made and tested.
2. If directed to restore service, notify spaces concerned that service is being restored.
3. Remove wire and tags from the valves or machinery units and remote control gear.
4. Return system to original condition or as directed.
5. Report to your MMC, engineer duty officer, or OOW when completed.

Typical Engineroom Casualties

The *Bureau of Ships Manual* recommends general procedures for the control of typical engineroom casualties. However, since even sister ships vary to a certain extent, you should be thoroughly familiar with your ship's Engineering Operation and Casualty Control Manual in order that you may know the engineering casualty procedures on your ship. The following engineering casualty proced-

ures are general in nature and do not apply to a specific ship.

LEAK IN CONDENSER. If a condenser salinity indicator shows a rise in the chloride content, the source of the contamination must be determined immediately. To locate these sources, test the fresh water from different units in the system by checking the proper salinity indicators (if installed) and by making chemical chloride tests. There are four possible causes of a salty condenser:

1. Leaky tube(s) in the condenser.
2. Make up feed tank salted up.
3. Low-pressure drain tank salted up.
4. Heating system drains salted up.

Each of the aforementioned possibilities must be investigated to determine the source of the contamination and its elimination.

If it is determined that there is a minor leak in the condenser and the ship's prospective arrival time is less than 24 hours, the affected plant will probably be continued in operation. Isolate the condensate system, limit the number of boilers on the engine involved. When operating under these conditions it will be necessary to blow down the boiler(s) as necessary, to keep the boiler salinity within the specified limit.

However, if the leak is serious, the following action should be taken:

1. Stop the engine.
2. Shift drains, auxiliary exhaust, and turbogenerator exhaust to the auxiliary condenser.
3. Retain the main lubrication oil system in operation, and proceed on the other engine(s).
4. Test the condenser and plug the leaking tube(s).

For the procedure in locating and plugging leaking condenser tubes, refer to chapter 7, Condensers and Other Heat Exchangers, in this training course.

DEAERATING FEED TANK WATER LEVEL DROPS DURING STEADY STEAMING. If a decrease in the deaerating

feed tank water level is noted during steady steaming, proceed as follows:

1. Check the condensate pump for operation.
2. Check to see that the manually operated recirculating valves are closed. (On a ship equipped with a bypass regulating valve around the air ejector unit, check the automatic valve for proper operation.)
3. Check the water level in the main condenser. Start the standby condensate pump, if the water level is too high. (Do this gradually paying close attention to the exhaust pressure.)
4. Check the other enginerooms for make-up or excess feed water conditions.
5. If these are satisfactory, take on make-up feed gradually.

DEAERATING FEED TANK TOO FULL. If the deaerating feed tank is too full, proceed as follows:

1. Check the operation of the feed-booster pump.
2. Check the make-up feed valve to be sure that it is closed.
3. If other engineroom(s) can take some feed, open the condensate cross-over valves and close off the condensate to the deaerating feed tank; or open the excess feed valve deaerating tank to feed bottom.

GAGE GLASS ON EVAPORATOR BREAKS. If a gage glass breaks on an evaporator, proceed as follows:

1. Secure the valve at top and bottom of the gage glass.
2. Remove any broken glass from the gage glass rubber gaskets. Obtain a replacement gage glass or cut replacement from glass tube stock.
3. Install the new gage glass.
4. Open the valves at top and bottom of the gage glass. Check the water level in the gage glass by looking through the glass port on the side of the evaporator shell.

5. If the gage-glass valves leak and vacuum is lost, secure the evaporators and install another gage glass.

COOLING WATER TO AUXILIARIES FAILS. If cooling water to any of the auxiliaries fails, proceed as follows:

1. Take cooling water from the fire main, and start the fire pump(s) as necessary.
2. Cross-connect the independent cooling water system, if provided.
3. A handy-billy and hose can be used for this if other means fail.

JAMMED THROTTLE. If the head throttle valve jams open, proceed as follows:

1. Close the guarding valve or main line stop valve.
2. Use astern throttle to stop the shaft in an extreme emergency.

If the astern throttle valve jams open, proceed as follows:

1. Close the line stop valve.
2. Use ahead throttle to stop the shaft in an extreme emergency.

RADIOLOGICAL MONITORING

The development of nuclear and thermonuclear weapons has progressed to a point where we are no longer limited to nominal-size atomic bombs. The thermonuclear bomb and the atomic cannon are a reality; atomic energy is being used in submarine engines; additional military applications of atomic energy are beyond the planning stage. In view of the unsettled international situation, there is always the possibility of an atomic attack. The threat of such an attack makes it essential that you be familiar with some of the facts concerning atomic warfare. Information dealing with how to protect yourself, your shipmates, and your ship in the event of an atomic attack is provided in the Navy training course, *Atomic*

Warfare Defense, NavPers 10097. This course will serve as an important source of information on what to expect and what to do in the event of an atomic attack.

One of the effects of an atomic attack would be nuclear radiation. The blast and thermal effects of an atomic explosion would cause extensive damage to materials; nuclear radiation, however, does not affect materials in any visible manner. Nuclear radiation is chiefly a hazard to personnel.

The powerful, penetrating radiation which is released by an atomic explosion may cause casualties if contamination is sufficiently great. The rays tend to destroy the body cells, especially the blood-forming cells. The extent to which nuclear radiation affects the body depends upon the length of time an individual is exposed to radioactive materials. As an MM3, you will be required to be able to use instruments which indicate the degree of RADIOLOGICAL CONTAMINATION present in drinking water.

In the event of an atomic attack, the sea water in the area around the explosion will be contaminated with radioactive particles. If a ship enters an area where the sea water has been contaminated in this way, there is a possibility that radioactive particles will find their way into the ship's drinking-water supply; the distilling plant must, therefore, be secured immediately. If sufficient concentration of radioactive particles is present, use of contaminated distillate may be harmful to personnel.

Radiation Detecting

The harmful consequences of radiation are the results of their ionizing effect on the human body. Although the body senses are well developed so that light and heat (comparatively low-energy, non-ionizing radiation) are easily detected in harmful amounts, the body senses are incapable of detecting the presence of ionizing radiation, even in amounts far greater than is necessary for early death.

For this reason, it is necessary to employ various

detection devices to measure ionizing radiation *when there is a possibility* that the ionization will represent a hazard to personnel.

Two distinct groupings of instruments are used in the detection and measurement of ionizing radiation—dose-rate meters and dosimeters. Together, the two groupings are called RADIAC INSTRUMENTS, the term being derived from the words "Radio Activity, Detection, Identification, and Computation."

Dose-rate meters indicate the intensity of an ionizing radiation at the location of the sensitive element of the detector.

Dosimeters indicate the total dose of ionizing radiation accumulated by the instrument during the time of exposure to radiation fields. This latter group of instruments will not be discussed in this training course. For information on dosimeters refer to chapter 4 in *Atomic Warfare Defense,* NavPers 10097.

The commonly used rate meters have a detection device, a power supply, an electronic amplification circuit, and a graduated meter reading directly in radiation dose rate. The portable instruments, called survey meters, are battery powered.

As a Machinist's Mate 3, you will be required to use radiac instruments for monitoring operations to determine the extent of radioactive contamination on intake lines and distilling plants.

Radiac Instrument Limitations

None of the radiac instruments, in current use, is capable of detecting and measuring all three of the types of nuclear radiation: alpha, beta, and gamma, at the same time. Even those instruments that can detect both beta and gamma radiation do not automatically separate these two types of radiation for us. Instead, it is left to the operator to keep beta particles from entering the ionization chamber by manually pulling a beta shield over a thin window in the detector probe to obtain a gamma

reading. To get a beta reading, you must subtract the gamma reading from the combined reading.

For alpha radiation, a separate instrument is used. This instrument measures alpha particles in disintegrations per minute per 150 square centimeters (the area of the window in the bottom of the radiac instrument). Due to the extremely high energy of alpha particles and their high degree of ionizing ability, it is possible to design an instrument which indicates alpha radiation alone.

Radiac instruments operate within specific ranges. Survey meters are calibrated to indicate radiation dosage rates from 0.5 milliroentgens per hour to 500 roentgens per hour (0.5 mr/hr to 500 r/hr), although in Navy equipment this wide a range is not found in one instrument. Instead, several instruments are used, each covering a portion of this range.

Typical Navy Radiac Instruments

The Navy uses three main survey meters: the high intensity survey meter (Hi-R survey), the low intensity survey meter (Lo-R survey), and the alpha survey meters.

Hi-R Survey-AN/PDR-18 Series

The AN/PDR–18 series radiac set (fig. 15–3) is a portable survey instrument consisting of a detector with a sensitive phosphor element which glows in the presence of gamma radiation, a photomultiplier tube which multiplies the extremely small current caused by the radiation, an electronic amplifier, a rate meter, and a combination battery and vibrator power supply. This instrument is designed to detect gamma radiation only. It measures high intensity gamma radiation over four ranges: 0 to 0.5 r/hr, 0 to 5 r/hr, 0 to 50 r/hr, and 0 to 500 r/hr. This instrument has a nine position, rotary, selector switch which is mechanically geared to the meter dial. The position of the switch at any particular time shows through an opening in the meter face. The positions and their indications are listed in the following table.

Position	*Indication*
OFF	Batteries disconnected; set will not operate.
A	Condition of filament batteries.
B	Condition of high voltage battery.
ZERO	Instrument ready for zero adjustment.
CAL	Meter ready to be calibrated for full scale deflection.
500	0 to 500 r/hr range.
50	0 to 50 r/hr range.
5	0 to 5 r/hr range.
0.5	0 to 0.5 r/hr range.

There is an illumination switch on the handle which turns on an internal lamp for lighting the meter face.

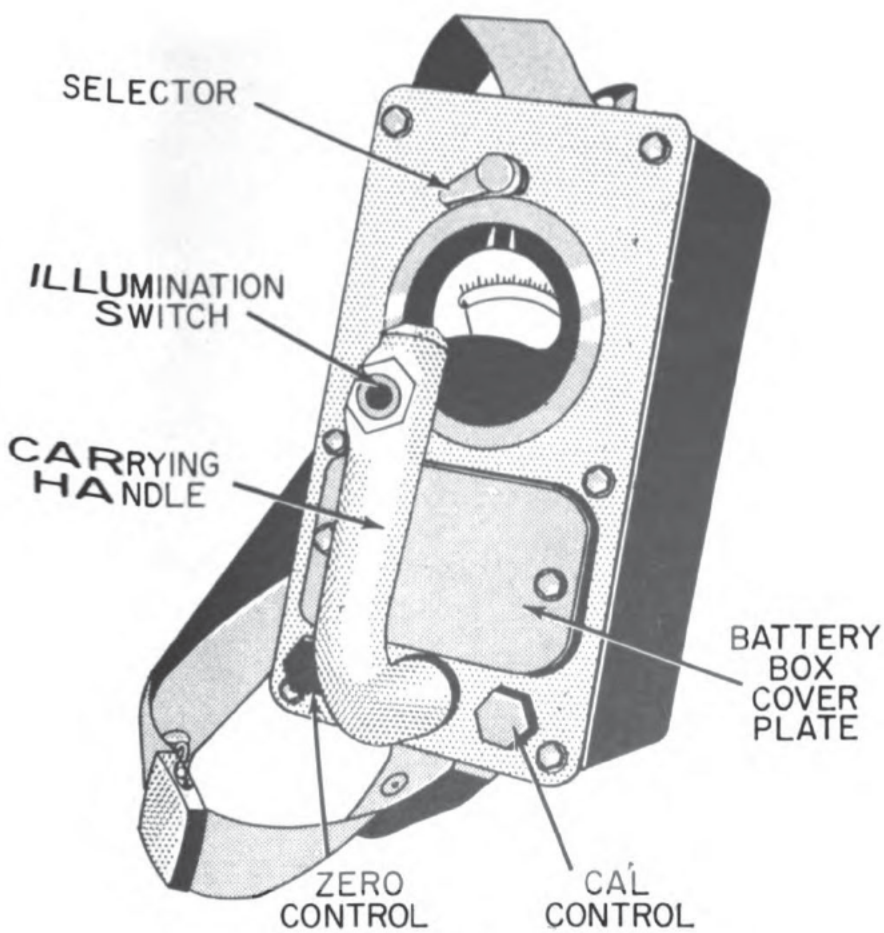

Figure 15-3.—Hi-R survey meter-AN/PDR-18B.

Lo-R Survey-AN/PDR-27 Series

The AN/PDR–27 series radiac set is a portable, water-ight survey instrument consisting of a low range Geiger-Müeller tube located in a probe, a higher range Geiger-Müeller tube located inside the case, an electronic ampli-ier, a battery power supply, a meter, and earphones (fig. 15–4). This instrument is capable of detecting and meas-uring beta and gamma radiations together, or gamma radiation alone.

The main unit of this radiac set, the radiacmeter, is

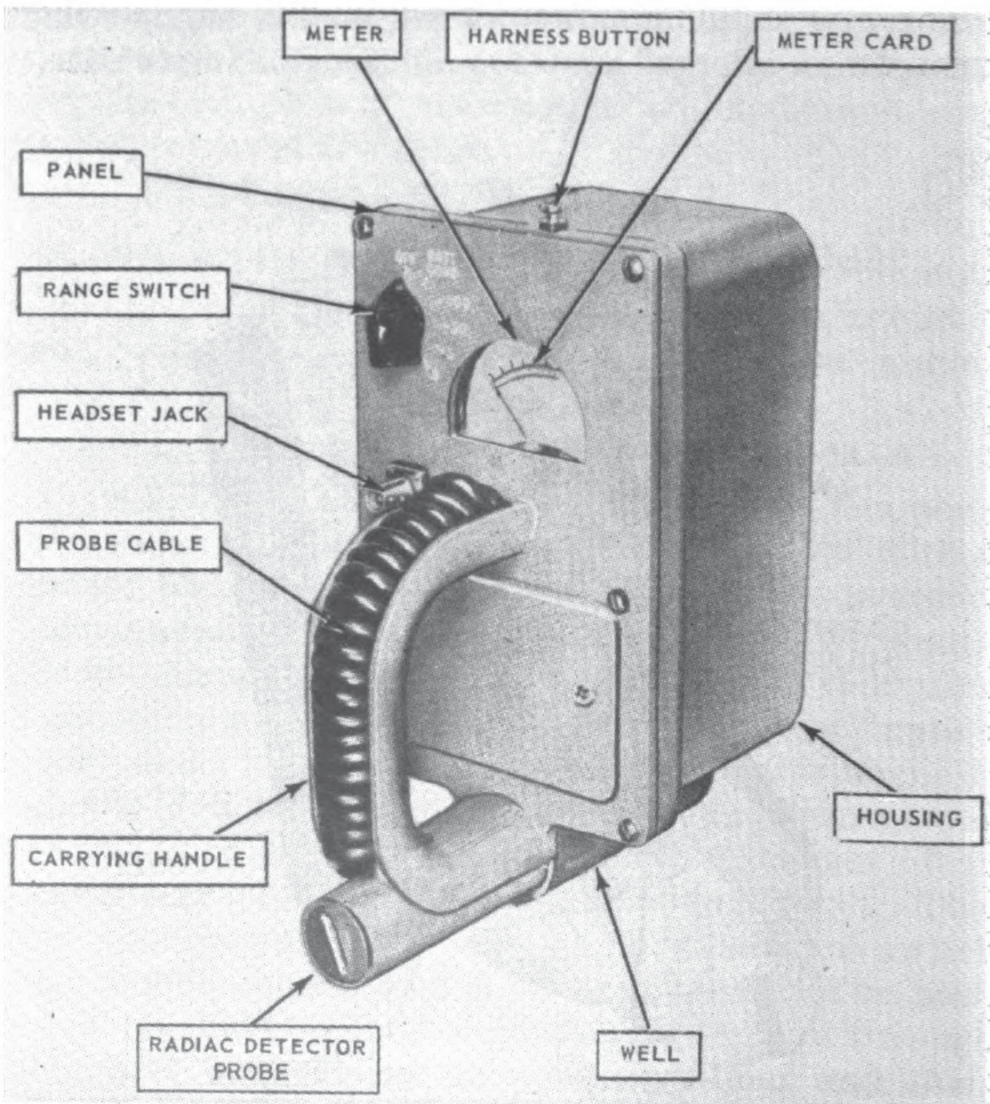

Figure 15–4.—Lo-R survey meter-AN/PDR-27 series.

equipped with a carrying handle and may also be carried by an externally connected shoulder harness. The detector unit is contained in a probe attached externally, by means of a flexible cable, to the meter. The probe is normally carried in a "well" on the outside of the meter and can be easily removed. When measuring gamma radiation, the detector can be used in or out of the well; beta radiations, however, can be detected only when the detector is removed from the well and the beta shield on the probe is moved aside.

When the Geiger-Müeller tubes are exposed to gamma and beta radiation, they produce short voltage pulses at an average rate which depends on the radiation intensity in the vicinity of the tubes. The meter gives you a VISUAL indication of the radiation; earphones in which a click is heard for each pulse received are also provided.

Both Geiger-Müeller tubes, one in the probe and one in the case, are used for the two most sensitive ranges, 0 to 0.5 mr/hr and 0 to 5 mr/hr. Only the Geiger-Müeller tube in the case is used for the two least sensitive ranges, 0 to 50 mr/hr and 0 to 500 mr/hr.

This radiac instrument has a six position, rotary selector switch mechanically geared to the meter dial. The positions of the switch and their indications are shown in the following table.

Position	*Indication*
OFF	Batteries disconnected; set will not operate.
BATT-COND	Batteries' condition.
500	0 to 500 mr/hr range.
50	0 to 50 mr/hr range.
5	0 to 5 mr/hr range.
0.5	0 to 0.5 mr/hr range.

Only gamma radiation field strengths can be measured on the two less sensitive ranges.

The meter can be illuminated by tilting the radiac set case at an angle of about 45 degrees.

Alpha Survey-AN/PDR-10 Series

The AN/PDR–10 series radiac set is a portable instrument intended to detect and measure the intensity of alpha radiation. The set consists of an ionization chamber detector, an electronic amplifier, a meter, a battery power supply, and earphones (fig. 15–5). This instrument measures alpha radiation in disintegrations per minute per 150 square centimeters. which is the area measured by the window in the bottom of the case; that is, it measures the disintegration of atoms in an area of 150 square centimeters of any object. The indicator reads up to 10,000 counts per minute. Radiations are also indicated by clicks heard in the earphones.

This set has two switches, a function switch and a dis-

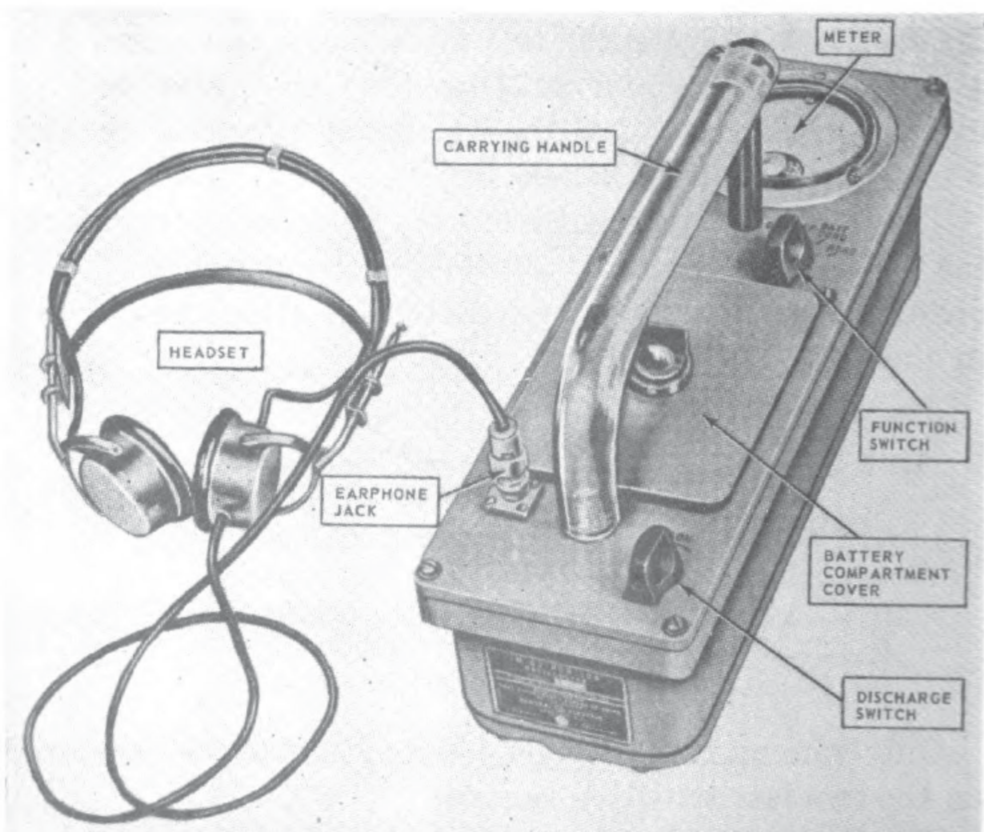

Figure 15–5.—Alpha survey meter-AN/PDR-10 series.

charge switch. The function switch has four positions which set the conditions shown in the following table.

Position	*Condition*
OFF	Batteries disconnected; set will not operate.
CHG	Storage capacitor that maintains high voltage across ionization chamber is charged.
BATT-COND	Batteries' condition.
READ	Presence of radiation is registered on the meter.

The discharge switch is a momentary contact that discharges the storage capacitor and the ion chamber. It is also used to correct a condition in the ionization chamber called corona, which means too high a voltage. This condition causes a hiss in the earphones when the function switch is in the READ position.

To permit reading the meter scale in the dark, a light is included in the meter. It is turned on by tilting the meter 45 degrees from the horizontal.

QUIZ

1. Which watch is responsible for checking the oil level in the main shaft spring bearings?
2. Who shifts and cleans the main lube oil strainers? How often are the main lube oil strainers cleaned?
3. Who regulates the main lube oil temperature?
4. What is the first action to be taken when a main condenser salts up?
5. What must be done if there is a serious leak in the main condenser?
6. What are the official legal records maintained by the engineering department of the ship?
7. How should errors be corrected on the official legal records maintained by the engineering department aboard ship?
8. What is done before any original page of the official legal records is sent away from the ship or commission to be used as evidence at a naval court?
9. Is the operation of all air compressors by power required by the daily, weekly, or monthly checkoff sheets?
10. To what smooth record cards are the data transferred from the workbooks?
11. When is main engine control informed that the engineroom watch is manned and ready to light off?
12. If a decrease in the water level of a deaerating feed tank is noted during steady steaming, what checks should be made?
13. If the ahead throttle valve jams, how can the shaft speed be controlled?
14. What instruments will Machinist's Mates use for detecting radioactive contamination in shipboard enginerooms?
15. Geiger-Müeller survey meters can be used for detection of
    (a) Alpha and beta radiation.
    (b) Only beta radiation.
    (c) Alpha and gamma radiation.
    (d) Beta and gamma radiation.
16. Which survey instruments are used by the Navy to detect only gamma radiation?
17. Which survey instruments are used by the Navy to detect only alpha radiation?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

PREPARING FOR ADVANCEMENT

1. Book knowledge, actual experience, and experiences of others.
2. Knowing more than is required makes you more of a master of what you must know; better prepares you for meeting emergencies; and tends to make you more eligible for advancement.
3. MMR.
4. Yes, that of being a military leader as a petty officer.
5. *Bureau of Ships Manual.*
6. *Basic Machines, Basic Hand Tool Skills, Blueprint Reading, Mathematics*, and *Basic Electricity.*
7. The log room.

CHAPTER 2

ENGINEERING PIPING SYSTEMS

1. The pressure surrounding the liquid.
2. Saturated steam.
3. At the turbines.
4. The temperature of the feed water is raised.
5. Separate machinery rooms and spaces provide protection against enemy action, prevent loss of all machinery functioning in event of flooding, and eliminate interference with the operation of the machinery.
6. To make each machinery room independent of each other.
7. The main steam system, the 600 psi and 150 psi auxiliary steam systems, and auxiliary exhaust.
8. For maximum fuel economy.
9. By securing the cross-connection between the main propulsion units of a machinery group and also securing the cross-connection between the turbogenerators of the same group.
10. To the (a) main propulsion turbines, (b) turbogenerators, and (c) soot blowers.

11. By manual operation of the guarding valve.
12. By opening the necessary cutout valves.
13. The 150 psi auxiliary (low-pressure) steam system.
14. The 600 psi auxiliary steam system and the auxiliary exhaust steam system.
15. The bleeder valve must be opened before disconnecting the steam hose.
16. Deaerating feed heaters, distilling plant, and the turbine glands.
17. 10 to 25 psi.
18. a, c, and d.
19. One-fifth to one-fourth.

CHAPTER 3

MAIN AND AUXILIARY TURBINES

1. Geared-turbine and turboelectric.
2. High-pressure, low-pressure, astern, and cruising. The cruising turbine.
3. A separate cruising turbine reduction gear.
4. By switch gear equipment to the electric motors.
5. (a) By basic impulse and reaction principles, (b) by pressure and velocity staging, (c) by division of steam flow, (d) by direction of steam flow.
6. It is absorbed by the moving blades, which are attached to the turbine wheel.
7. The nozzles. To lower the pressure and increase the velocity.
8. A single nozzle or set of nozzles combined with a single row of moving blades. Rateau stage. Pressure remains constant.
9. The utilization of more than one pressure and/or velocity within a single turbine.
10. The steam pressure is expanded from a high inlet pressure to a low exhaust pressure in a succession of drops.
11. That within one individual pressure stage there will be two or more successive drops in steam velocity.
12. Rateau turbine. Yes.
13. A turbine comprising more than one pressure stage but employing velocity staging in each pressure stage.
14. The single rows of moving blades separated by single rows of fixed blades in the Rateau turbine are changed to two or three rows of moving blades separated by single rows of fixed blades in the Curtis turbine.

15. (a) Simple impulse turbines, (b) velocity-compounded impulse turbines, (c) pressure-compounded impulse turbines, (d) pressure-velocity-compounded impulse turbines, (e) pressure-compounded reaction turbines, (f) combination impulse and reaction turbines.
16. By adding additional rows of moving blades on the single rotating wheel, and thus utilizing in each successive row some velocity not used in the preceding row.
17. High pressure. No.
18. Separate shafts.
19. In the same casing which houses the low-pressure turbine unit.
20. Double-flow.
21. Both.

CHAPTER 4

TURBINE PARTS AND ACCESSORIES

1. (a) Elongated bolt holes or grooved sliding seats, to permit fore-and-aft movement; (b) a deep flexible I-beam, which expands to an undeflected position at maximum turbine speeds.
2. To allow for expansion of the steam line and to relieve strain on the turbines resulting from thermostress.
3. Nozzle controls.
4. To minimize the flow of steam between the nozzle diaphragm and the rotor of the turbine.
5. To dissipate quickly the friction heat and transfer it to the lube oil.
6. It permits a small amount of shell movement to compensate for minor misalinements of the shaft.
7. Pivoted shoe (also known as Kingsbury).
8. To prevent air from flowing into the vacuumized space inside the casing, and eventually to the condenser. About 2 psi gage.
9. Labyrinth packing glands, carbon packing glands, and a combination of labyrinth and carbon packing glands. The combined form of labyrinth and carbon packing glands.
10. To put a slight vacuum on the gland seal leak-off piping, which draws the leak-off steam to the gland exhaust condenser.
11. The setting of the cam-operated nozzle control valves.
12. Constant-speed and speed-limiting governors.
13. The back-pressure trip.
14. The flyweights move outward while the pilot valve moves downward.

CHAPTER 5

REDUCTION GEARS, BEARINGS, SHAFTING, AND PROPELLERS

1. By use of reduction gearing or an electric drive.
2. Transmit rotary motion from one shaft to another at a reduced speed.
3. By connecting the two through means of a reduction gear.
4. Locked train double reduction gear.
5. Double helical type.
6. Helical gears produce smoother action and avoid tooth shock.
7. Every day, at least 1¼ revolutions.
8. Either at the forward end of the main reduction bull gear or in the propeller line shafting aft of the bull gear.
9. Oil, from the main thrust sump, is delivered by either an electric-driven or chain-driven gear-type pump.
10. Segmented pivoted shoe (Kingsbury-type thrust bearing).
11. By brass oiler rings passing through the oil reservoir.
12. Prevents excessive leakage of sea water into the ship.
13. Composition bushings—rubber, lignum vitae, or laminated phenolic.
14. Constant pitch, variable pitch, and controllable pitch.
15. The oil becomes aerated, its temperature rises, and the oil may overflow from the escape vent in the top of the gear casing.
16. Insufficient lubrication, dirty oil, and corrosion.
17. 2190 T.

CHAPTER 6

LUBRICATION

1. A resistance to motion offered by the surfaces of two bodies in contact.
2. (a) Sliding, (b) rolling, and (c) fluid.
3. To substitute fluid friction for either rolling or sliding friction. To absorb and remove heat.
4. That there are three layers or films of oil existing between the two moving surfaces of a bearing: two boundary films (one next to the rotating journal and one next to the stationary lining) and an intermediate fluid film.
5. Where no water is present and where operating temperatures approach 200° F.

6. It (a) serves as abrasive to smooth any rough surfaces, (b) fills in unequal surface spots, and (c) substitutes its own low friction for that of the metal it covers.
7. The tendency of oil to resist flow or change of shape.
8. That the viscosity of the oil varies less with changes in temperature.
9. The temperature at which the oil will continue to burn when ignited.
10. Its ability to separate cleanly from any water present.
11. The last three digits indicate the viscosity.
12. That it takes 80 seconds for 60 cubic centimeters of the oil, at 210° F, to flow through the orifice of a Saybolt viscosimeter.
13. With the use of a priming pump.
14. A tank where engine oil is heated to 180° F, then left standing at this temperature for several hours to allow the impurities to settle to drains at the bottom of the tank.
15. It must not exceed 50° F.
16. Bearing caps should be felt continually, and the sight glasses should be inspected to ensure a positive flow of oil.
17. Once each watch.
18. (a) Increase of frictional resistance, (b) premature breakdown of oil film, and (c) corrosion of the bearing journals.
19. Atmospheric moisture enters these vents and condenses.
20. They oxidize.
21. Drip-feed and wick-feed.
22. It causes the chain to wear rapidly and a hole to be worn through the bottom of the oil sump.
23. Contamination or the formation of sludge.
24. Tubular-bowl type and disk-type.
25. As a separator.

CHAPTER 7

CONDENSERS AND OTHER HEAT EXCHANGERS

1. By removing the latent heat of vaporization.
2. To keep the condenser as free as possible from sea life and debris.
3. Allows for some thermal expansion of the tubes, and provides for drainability during idle periods.
4. By an application of asphalt paint or shellac.
5. Once each month; oftener if necessary.
6. By brushing with a wire brush, or by using an air lance.
7. As soon as there is sufficient condensate in the hotwell.

8. By securing the first-stage steam on the air ejector after the throttle valve has been secured.
9. Connect a line from the auxiliary exhaust to the steam connection on the lube oil cooler and warm the oil.
10. 15 psi.
11. From the fire main.
12. Condensate from the main or auxiliary condenser.
13. When the condenser vacuum rises to or above 20 inches.
14. Supplying steam at operating pressures, (b) providing a sufficient flow of cooling water through the inter- and after-condenser, and (c) maintaining proper drainage of inter- and after-condenser, and the steam line to the ejector.
15. A loss of vacuum will result.
16. Secure the first-stage suction valve.
17. (a) Heating, (b) deaerating, and (c) storing feed water.
18. 15 psig.

CHAPTER 8

PUMPS

1. Direct-acting.
2. Double-acting.
3. The steam piston is larger in diameter than the pump plunger.
4. It provides automatic timing of the admission and release of steam to and from each end of the steam cylinder.
5. An air chamber and a snifter valve.
6. By causing the pilot valve to block the ports, thus disturbing the admission of steam to the main valve.
7. By moving the tappet collars farther apart.
8. The position of the tilting box.
9. The floating ring must be off-center from the pump shaft.
10. A pump which delivers a definite amount of liquid on each stroke or each rotation.
11. One with a relatively small number of large teeth.
12. (a) The replaceable inserts take up some of the wear which would otherwise be sustained by the lobes; and (b) they maintain a tight seal between the lobe ends and the casing.
13. (a) The volute pump, and (b) the volute turbine pump.
14. In the volute; or in the volute and in the diffuser.
15. To prevent the pump from becoming vapor bound.
16. Approximately every 2 months.
17. The feed-booster pump decreases in speed.
18. Eductors.

CHAPTER 9

PIPING, VALVES, AND PACKING

1. By its inside diameter dimension. By outside diameter.
2. Standard, extra strong, and double extra strong.
3. Yes. No.
4. By the nominal outside diameter.
5. Nonferrous material.
6. External surfaces should be kept properly painted and free of moisture.
7. A dangerous blowout may result from progressive growth of the leak.
8. Make slight alterations in the anchorages, connections, hangers, or leads of the piping. Fit piping with supports.
9. For joining piping up to 2 inches in size.
10. Yes.
11. (a) Butt-weld, (b) fillet-weld, (c) socket-weld.
12. Below 425° F for steam lines. Below 3000 psi for cold lines.
13. (a) Slip joint, (b) U-bend sections, (c) corrugated joints, (d) bellows joints.
14. By removing the lower bonnet.
15. Small spring-loaded valves sometimes attached to the inner chamber of relief valves. To give warning of dangerous pressures.
16. When a fixed pressure differential is required between the discharge pressure of the pump and the pressure of the unit supplied by the pump.
17. To prevent water hammer and erosion.
18. Wire drawing and erosion.
19. Setting up on the gland or repacking.
20. Gate, globe, and stop-check valves.
21. The yoke nuts should be carefully slacked until the disk can be freed.
22. Failure of the securing device or corrosion through the stem.
23. Lathe or valve reseating machine. The latter is preferred, because the work can be done with the valve body in place.
24. By coating the surface of the disk with prussian blue. Insert the disk in the valve and rotate a quarter turn. Check for prussian blue at points where disk and seat touch. Spotting-in.
25. (a) Those which slide, (b) those which rotate, (c) those operating helically and intermittently, and (d) those which are fixed.
26. Square.

27. (a) Serrated-face metal gaskets and (b) spiral-wound, metallic-asbestos gaskets.
28. Coat one side with graphite.
29. Predominant material of which the packing is composed.
30. V-type.
31. A soft packing.
32. Heavy, asphalt-impregnated paper.
33. With an inner layer of a diatomaceous earth material and an outer layer of magnesia-asbestos material.
34. By applying insulating cement.
35. Can be mixed with water and reused in plastic form.

CHAPTER 10

DISTILLING PLANTS

1. An evaporator or boiler and a distiller or condenser.
2. Low-pressure steam plants.
3. Soloshell double-effect type.
4. First- and second-effect evaporator shells.
5. A tubular surface multi-pass heat exchanger.
6. Air ejector.
7. Fresh water system.
8. In the condensate lines.
9. 1 to 5 psig.
10. Auxiliary exhaust line.
11. The steam generated in the evaporator shells by the evaporation of the feed (sea) water.
12. A series of baffles above the surface of the water in the evaporator shell and by additional baffles or waves in the first-effect vapor separator.
13. In the distilling condenser.
14. 135 psig.
15. The sea.
16. Two.
17. A portion of the sea water from the circulating water circuit.
18. To prevent water from siphoning into the last effect as the vacuum is obtained.
19. To the top of the tubes.
20. Open the discharge valve on each drainer, so that the distilled water will be carried to the flash chamber.
21. 1.5 thirty-seconds.
22. The fresh water meter or pump discharge valve must be secured, and the water from the test tank must be drained into the bilge.

23. To prevent priming.
24. Approximately 26 inches.
25. To prevent priming when the ship rolls.
26. One thirty-second.
27. Care must be taken to keep the packing glands sealed at all times.
28. At 15-minute intervals.
29. Cornstarch minimizes priming, and boiler compound combats tube scaling.
30. Differential expansion and contraction, which breaks the scale loose from the tubes.
31. Close the air suction valve between the distilling condenser and the air ejector.
32. To equalize the pressure in all units of the plant.
33. Prevents maintenance of the brine density at 1.5 thirty-seconds.
34. A reduced or fluctuating vacuum.
35. 0.065 epm.

CHAPTER 11

REFRIGERATION

1. (a) Amount of heat.
2. It is the amount of heat required to raise the temperature of 1 pound of water 1° F at atmospheric pressure.
3. Latent heat.
4. Heat that causes a change in temperature when added to or removed from a substance.
5. No—and it is not possible, either.
6. 5 Btu.
7. A unit used to describe the transfer of 288,000 Btu in 24 hours.
8. It serves to dispose of the heat absorbed in the low-pressure side, and to get the refrigerant back into a liquid state so that it can again vaporize in the evaporator and thus absorb heat.
9. The temperature of the refrigerant near the evaporator outlet.
10. The superheat increases the efficiency of the plant; and, by drying the vapor, prevents liquid carry-over to the compressor.
11. It raises the pressure of the vaporized refrigerant sufficiently high to permit heat transfer to take place in the condenser.
12. The solenoid valve keeps the spaces from becoming too cold at light loads.
13. The KING solenoid valve.

14. Near the outlet of each evaporator EXCEPT the evaporator in the space in which the lowest temperature is to be maintained.
15. The low-pressure cutout switch.
16. To the suction side of the compressor.
17. When the condenser and the receiver are located a considerable distance below the thermostatic expansion valve.
18. It can cause permanent damage by freezing the tissues of the eye.

CHAPTER 12

AIR COMPRESSORS

1. High pressure.
2. By use of reducing valves.
3. Completely independent.
4. Suction valves.
5. In cubic feet of free air per minute at intake temperature and pressure. In cubic feet of compressed air per hour at intake temperature and discharge pressure.
6. By an electric motor.
7. It distributes side pressure thereby helping to prevent cylinder wall wear.
8. 1 to 6 drops of oil feed per minute.
9. Second stage intercooler.
10. To remove heat of compression and to condense moisture.
11. It is present in the intake air.
12. The receiver (accumulator).
13. Be sure that the power is off.
14. That the bushing is worn and requires replacement.
15. Every three months.
16. They vaporize readily and form an explosive mixture with air under compression.
17. Once each watch.
18. They may cause abnormally high temperatures and eventually an explosion.

CHAPTER 13

STEERING ENGINES, DECK MACHINERY, AND ELEVATORS

1. When they are operated by enclosed liquids under pressure.
2. (a) Electrohydraulic, (b) electromechanical, (c) steam-driven.

3. (a) Electrical, by means of an a-c synchronous transmission system; (b) hydraulic, by means of a hydraulic telemeter system.
4. The air cocks must be opened, the charging pump operated until oil escaping from these air cocks is free of bubbles, and then the air cocks closed.
5. From —24° to —40° F.
6. To prevent the entry of foreign matter into the system and to prevent the entry of air bubbles into the hydraulic system.
7. The angle of the tilting box.
8. Coat with a thin-film of rust-preventive compound (Stock No. 52-C03257) or heavy oil (e. g., symbol 4065).
9. About every 6 months.
10. At least twice a week.
11. Right-and-left screw, or worm gears and quadrant.
12. A reversing throttle valve or a link mechanism.
13. Drain all the water from the cylinders.
14. (a) The direct-plunger lift and (b) the plunger-actuated cable lift.
15. Automatic quick-closing valves in the hydraulic fluid line.
16. A maximum temperature of 135° F.
17. By escape of oil from the high-pressure side of the line leading into the expansion tank, or by a failure of the pressure control.
18. By shifting to steering aft.
19. Neutral.

CHAPTER 14

INDUSTRIAL GASES

1. You would DEFINITELY NOT follow such a suggestion. It is true that a candle would go out in CO_2 and flare up in oxygen, but other flammable or explosive gases might be present. It might be like looking in a gasoline tank with a lighted match.
2. Ethyl chloride, hydrogen, propane, methyl chloride. A mixture of ammonia and air may explode, but ammonia is not considered flammable.
3. At pressures above 15 psi acetylene tends to explode spontaneously.
4. CO_2 is not detectable by odor or color; it is heavier than air and will accumulate in low places. Thus, it can collect in dangerous quantities, and can overcome men exposed to it without warning.
5. A propellant to disperse the insecticide as a spray in the atmosphere.

6. Artificial respiration.
7. Nitrogen is inert under ordinary conditions but it does combine with other elements as is shown by the existence of the nitrates used in fertilizing and in explosives.
8. Oxygen, acetylene, Freon, carbon dioxide.
9. When any given amount of gas is put under pressure, the pressure multiplied by the volume will always give the same figure if the temperature remains constant.
10. The amount of heat which can be removed from the substance without changing its temperature during the change from a gaseous to a liquid state.
11. With a soapy solution.
12. Acetylene.
13. Oxygen (aviator's). Any Freon.
14. To produce liquid CO_2 from ordinary diesel fuel oil.

CHAPTER 15

WATCHES AND CASUALTY CONTROL

1. Shaft alley watch.
2. The oiler. Once a watch.
3. The lube oil pump watch stander.
4. Determine the source and make a chloride test of the fresh water from the different units in the system.
5. Locate and plug the leak.
6. The Engineering Log and the Engineer's Bell Book.
7. They should be overlined, initialed, and, if practicable, the correct entry made immediately following the entry struck out.
8. A certified copy of the page is made for the ship's file.
9. Weekly.
10. Machinery History Cards.
11. When all the watch standers have mustered in the engine-room.
12. Check the condensate pump, the recirculating valves, and the water level in the main condenser.
13. By manually closing the guarding valve or the main line stop valve.
14. Radiac instruments.
15. (d).
16. AN/PDR–18 series or Hi-R survey meters.
17. AN/PDR–10 series or Alpha survey meters.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

MACHINIST'S MATES (MM)

Quals Current Through Change 10

General Service Rating

Scope

Machinist's mates operate, maintain, and make repairs to ship propulsion and auxiliary equipment such as steam propulsion machinery, shafts, propellers, evaporators, compressors, pumps, valves, oil purifiers, heat exchangers, governors, and reduction gears; maintain and make repairs to outside machinery such as steering engine, anchor windlass, cranes, elevators, food preparation and related utility equipment, and winches; operate, maintain, and repair refrigeration and air conditioning equipment; may perform duties in the generation, stowage, and transfer of the following industrial gases: oxygen, carbon dioxide, nitrogen, and acetylene.

NOTE.—Personnel in the GENERAL SERVICE RATING will not be examined in industrial gas.

Emergency Service Ratings

MACHINIST'S MATES L (General Machinist's Mates), Rating Code No. 3701........... MML

Operate, maintain, and make repairs to main propulsion and auxiliary machinery of steam-propelled vessels.

MACHINIST'S MATES R (Refrigeration Mechanics), Rating Code No. 3702.................. MMR

Operate, maintain, and repair refrigeration and air conditioning equipment.

MACHINIST'S MATES G (Gas Generating Mechanics), Rating Code No. 3703......... MMG
Operate and maintain machinery for generating and compressing industrial gas and for charging compressed-gas containers.

Navy Enlisted Classification Codes

For specific Navy enlisted classification codes included within this rating, see Manual of Navy Enlisted Classifications, NavPers 15105 (Revised), codes MM–4200 to MM–4299.

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
100 PRACTICAL FACTORS				
101 OPERATIONAL				
1. Start, operate, stand watch on, and secure double- or triple-effect distilling plants	3	3	-----	-----
2. Stand watch in steering engine room	3	3	-----	-----
3. Use radiac instruments and perform monitoring operations on intake lines and evaporators	3	3	-----	-----
4. Operate a CO_2 plant, refill CO_2 cylinders, and take gas analysis test during operation	-----	-----	-----	3
5. Operate compressors and motors and take gas analysis test on an oxygen plant and log readings on a CO_2 and acetylene plant	-----	-----	-----	3
6. Operate and stand watch on CO_2 and oxygen transfer equipment	-----	-----	-----	3
7. When warming up main steam-propulsion machinery fitted with reduction gear and motor-driven turning gear:				
a. Measure turbine clearances where indicators are installed. Specify that they are cold readings	C	C	-----	-----
b. Back all throttle valves off seat and reseat lightly by hand	1	1	-----	-----
c. Check for water in lubricating oil and use lubricating oil purifier if necessary	2	2	-----	-----
d. Heat lubricating oil in sump tank to 90° F. and secure steam to heating coils	2	2	-----	-----

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
101 OPERATIONAL—Continued				
e. Clean all oil and bilge strainers	3	3		
f. Ease up on stern tube gland, allowing a small amount of water to leak through the gland	3	3		
g. Line up lubricating oil system	2	2		
h. Start lubricating oil pump	2	2		
i. See that oil is delivered to turbines, reduction gears, and trust bearings. Inspect for leaks	3	3		
j. Open all drain valves on main steam line	3	3		
k. Test low-pressure lubricating oil alarm system	2	2		
l. Test standby lubricating oil pump	2	2		
m. Obtain permission from bridge and start motor-driven turning gear and jack over main engine	1	1		
n. Open main injection and overboard discharge valves	3	3		
o. Start main circulator pump	2	2		
p. Start main condensate pump and recirculate water	2	2		
q. Cut in gland seal on turbine	2	2		
r. Start second stage air ejector; build up vacuum on main condenser	1	1		
s. Vent main condenser to insure that condenser is not air bound	3	3		
t. Open all auxiliary low-pressure drains to main condenser. Secure auxiliary condenser and cut auxiliary exhaust steam not used elsewhere into main condenser	3	3		
u. Line up system and recirculate water through deaerating tank	1	1		
v. Open drains to whistle and siren	3	3		
w. Cut in steam to whistle and siren	3	3		
x. Warm up main feed pump and booster pump	1	1		
y. Test engine telegraph	1	1		
z. Take and log counter readings	1	1		
aa. Put main feed pumps on line	1	1		

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
101 OPERATIONAL—Continued				
bb. Open bulkhead stops to throttle or nozzle control valves	2	2	-----	-----
cc. Close throttle bypasses and warming-up valves	1	1	-----	-----
dd. Obtain permission from bridge and turn main engines	1	1	-----	-----
ee. Disengage motor-driven turning gear	1	1	-----	-----
ff. Obtain permission from bridge and spin main engines	1	1	-----	-----
gg. Take and record hot turbine clearances	C	C	-----	-----
hh. Start first-stage air ejector; build vacuum to maximum obtainable	1	1	-----	-----
ii. Line up main lubricating oil cooler	3	3	-----	-----
jj. Make final inspection preparatory to reporting engine room ready to answer all bells	C	C	-----	-----
8. When securing main steam propulsion machinery fitted with reduction gears and motor-driven turning gear:				
a. Secure throttle valves	2	2	-----	-----
b. Rotate turbine rotors with shaft turning gear	1	1	-----	-----
c. Maintain lubricating oil pressure in all bearings during rotation	2	2	-----	-----
d. Secure main steam line and drain thoroughly before securing drains	3	3	-----	-----
e. Open turbine drains	3	3	-----	-----
f. Secure steam to first-stage air ejectors	1	1	-----	-----
g. Start auxiliary condenser and cut auxiliary exhaust and low-pressure drains into it	1	1	-----	-----
h. Start auxiliary and secure main feed pump	1	1	-----	-----
i. Continue operating turning gear and circulating lubricating oil through the system for at least 1 hour after gland steam has been secured	1	1	-----	-----
j. Secure steam to second-stage air ejectors	1	1	-----	-----
k. Secure gland seal steam and condensate pumps	2	2	-----	-----

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
101 OPERATIONAL—Continued				
l. Complete securing of air ejectors and break vacuum through air ejector suction	1	1	-----	-----
m. Secure main circulating pumps	2	2	-----	-----
n. Close main injection and overboard discharge valves	3	3	-----	-----
o. Inspect to insure that all root, throttle, exhaust, and drain valves of all auxiliaries not in use are closed	2	2	-----	-----
p. Drain waterside of oil coolers to bilges	3	3	-----	-----
q. Close turbine and steam line drains after 24 hours	3	3	-----	-----
9. Start, operate, stand watch on, and secure refrigeration and air conditioning systems	2	-----	3	-----
10. Start, operate, and secure Diesel generator used for power supply to oxygen plants	-----	-----	-----	2
11. Start, operate, and secure Diesel generator used for an acetylene plant	-----	-----	-----	2
12. Operate engine lathe for cutting threads and tapers and for plain turning	1	1	-----	-----
13. Start, operate, and secure an oxygen plant	-----	-----	-----	1
14. Select a site and set up industrial gas generating, stowage, and transfer equipment	-----	-----	-----	C
102 MAINTENANCE AND/OR REPAIR				
1. Change strainers and clean filters on gas generating equipment	-----	-----	-----	3
2. Lubricate all pumps and compressors used in gas generating plants	-----	-----	-----	3
3. Remove scale from evaporator tubes by cold shocking	3	3	-----	-----
4. Spot and grind in valves	3	3	3	3
5. Renew bonnet gaskets in valves	3	3	3	3
6. Repack stuffing boxes on centrifugal pumps with specified packing	3	3	3	3
7. Replace zinc plates in main and auxiliary condensers	3	3	-----	-----
8. Clean salt-waterside of main and auxiliary condensers	3	3	3	-----

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
102 MAINTENANCE AND/OR REPAIR—Continued				
9. Remove drying agent from adsorbers on an oxygen plant and refill	----	----	----	2
10. Repack valves using specified type of packing on gas generating equipment	----	----	----	2
11. Change oil and lubricate Diesel generators used for power supply on gas generating plants	----	----	----	2
12. Make minor repairs to insulation or lagging on piping	2	2	2	2
13. Remove scale from evaporator tubes chemically	2	2	----	----
14. Fit piston rings to steam cylinder of reciprocating pumps	2	2	----	----
15. Spot-in slide valve on steam chest of reciprocating pump	2	2	----	----
16. Test and renew suction and discharge valves on air compressors	2	2	2	2
17. Use dial indicators, micrometers, depth gages and inside-outside vernier calipers to take clearances on journals and bearings	2	2	2	2
18. Check for noncondensible gases and pump down refrigerant systems	2	----	2	2
19. Use halide torch on refrigeration or air conditioning equipment to test for leaks	2	----	2	2
20. Clean air ejector steam strainers	2	2	----	----
21. Clean inner and after air ejector condenser tubes	2	2	----	----
22. Reface valve seats and discs	2	2	2	2
23. Replace regulating valve diaphragms	2	2	2	2
24. Repack high-pressure valves	2	2	2	2
25. Spot in and replace bearings on centrifugal pumps	2	2	2	2
26. Replace oil seals on refrigeration compressors	1	----	2	2
27. Inspect, dry out, and recondition oxygen and CO_2 cylinders	----	----	----	1
28. Dehydrate, test, and recharge refrigeration systems	1	----	1	1
29. Inspect and recondition acetylene cylinders	----	----	----	1

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
102 MAINTENANCE AND/OR REPAIR—Continued				
30. Check alinement of couplings and determine clearances of bearings on pumps for gas generating equipment	----	----	----	1
31. Set all relief valves to required pressure	1	1	1	1
32. Repair centrifugal pump pressure regulators	1	1	1	1
33. Spot in or replace carbon packing rings on centrifugal pumps	1	1	----	----
34. Take clearances and replace wearing rings on centrifugal pumps	1	1	1	1
35. Check for alinement of centrifugal pump driving unit	1	1	1	1
36. Make air and soapsuds test on main and auxiliary condenser	1	1	----	----
37. Replace worn or broken reciprocating pump piston rings	1	1	----	----
38. Aline upper and lower cylinders of reciprocating pumps	1	1	----	----
39. Adjust slide valve on steam and exhaust side of reciprocating pumps	1	1	----	----
40. Adjust air ejector steam reducing valve	1	1	----	----
41. Adjust air ejector thermostatically controlled recirculating valves	1	1	----	----
42. Adjust tappets for proper piston stroke on reciprocating pumps	1	1	----	----
43. Grind in or replace valve discs and seats in water end of reciprocating pump	1	1	----	----
44. Renew weak or broken valve springs in water end of reciprocating pump	1	1	----	----
45. Remove scores from cylinder wall of water end and steam end of reciprocating pump	1	1	----	----
46. Renew packing rings in water end of reciprocating pump	1	1	----	----
47. Test evaporator tubes hydrostatically for leaks	1	1	----	----
48. Make repairs to pumps and compressors on gas generating equipment	----	----	----	C
49. Plug and replace condenser tubes	C	C	C	C
50. Set hydraulic speed limiting governor on centrifugal pumps	C	C	----	----

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
102 MAINTENANCE AND/OR REPAIR—Continued				
51. Set hydraulic pressure governor on centrifugal pumps	C	C	-----	-----
52. Set geared centrifugal fly-ball type governor on centrifugal pumps	C	C	-----	-----
53. Clean first- and second-stage air ejector nozzles and diffusers	C	C	-----	-----
54. Take main turbine and reduction gear bearing clearances, thrust clearances, and turbine blade clearances	C	C	-----	-----
103 ADMINISTRATIVE AND/OR CLERICAL				
1. Locate and use appropriate sections of the BuShips Manual, manufacturers' instruction books, mechanical drawings, and handbooks to obtain data when repairing machinery	1	1	1	1
2. Supervise and train personnel in operation, maintenance, and repair of:				
a. All engine room equipment	C	C	-----	-----
b. Refrigeration and air conditioning equipment	C	-----	C	-----
c. Gas generating equipment	-----	-----	-----	C
3. Take charge of an engine room watch on steam-propelled vessel	C	C	-----	-----
4. Take charge of a watch on gas generating equipment	-----	-----	-----	C
5. Keep engine room records and prepare naval shipyard and tender work requests	C	C	C	C
6. Estimate time and material needed for repair of auxiliary and main propulsion machinery	C	C	-----	-----
200 EXAMINATION SUBJECTS				
201 OPERATIONAL				
1. Safety precautions involved in performing tasks appropriate to applicable rates listed under 100 Practical Factors.				

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
201 OPERATIONAL—Continued				
2. First-aid procedures in instances of exposure to refrigerants in liquid or gaseous states and in instances of electrical shock and heat exhaustion	3	3	3	3
3. Safety precautions to be observed when working on shipboard machinery, taking on fuel, and moving or lifting heavy objects	3	3	3	3
4. Safety precautions to be observed when generating, transferring, stowing, and handling industrial gases	----	----	----	3
5. Uses and characteristics of industrial gases and their identification by standard markings on containers	3	3	3	3
6. Purpose and principles of operation of:				
a. Reduction gears	3	3	----	----
b. Double- and triple-effect distilling plants	3	3	----	----
c. Compressors	3	3	3	3
d. Main and auxiliary condensers	3	3	----	----
e. Lubricating oil purifiers	3	3	----	----
f. Air ejectors	2	2	----	----
g. Rotary, reciprocating, and centrifugal pumps	2	2	2	2
h. High- and low-pressure turbines	2	2	----	----
i. Turning gears	2	2	----	----
j. Steering engines	2	2	----	----
k. Relief valves	2	2	2	2
l. Turbogenerators	2	2	----	----
7. Construction and operation of Freon-12 type of refrigerating units. Characteristics of refrigerants	2	----	3	3
8. Power, fuel, water, chemicals, and other consumable materials required for operation of gas generating plants	----	----	----	2
[9. Principles of operation of oxygen, CO_2, and acetylene generating plants and associated equipment	----	----	----	2
10. Tests required by the Interstate Commerce Commission when shipping industrial gas containers	----	----	----	2

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
201 OPERATIONAL—Continued				
11. Purpose and principles of operation of:				
a. Refrigeration expansion valves	1	-----	2	2
b. Deaerating tank	1	1	-----	-----
c. Thrust bearings	1	1	-----	-----
d. Centrifugal pump governors	1	1	-----	-----
e. Gland sealing system	1	1	-----	-----
12. Methods and procedures for starting and securing steam turbine generator	1	1	-----	-----
13. Safety factors to be considered in selection of a site, and in installation of equipment, for oxygen, CO_2 and acetylene generating plants	-----	-----	-----	C
202 MAINTENANCE AND/OR REPAIR				
1. Chloride limits and frequency of tests on the following:				
a. Make-up feed water	3	3	-----	-----
b. Distiller discharge to reserve feed tanks	3	3	-----	-----
c. Main and auxiliary condensers	3	3	-----	-----
d. Reserve feed tanks	3	3	-----	-----
e. Deaerating and surge tanks on main feed line	3	3	-----	-----
2. Purpose and procedures for cold shocking evaporators	3	3	-----	-----
3. Procedures to be followed when:				
a. Changing and cleaning filters on gas generating equipment	-----	-----	-----	3
b. Lubricating gas generating equipment	-----	-----	-----	3
c. Repacking stuffing boxes on centrifugal pumps	3	3	3	3
d. Replacing zincs in main and auxiliary condensers	3	3	3	3
e. Removing drying agent from adsorbers on oxygen plant	-----	-----	-----	2
f. Removing scale from evaporator tubes	2	2	-----	-----
g. Fitting piston rings to steam cylinder of reciprocating pumps	2	2	-----	-----
h. Spotting-in slide valves on steam chest of reciprocating pumps	2	2	-----	-----

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
202 MAINTENANCE AND/OR REPAIR—Continued				
i. Testing and renewing suction and discharge valves on compressors	2	2	2	2
j. Spotting-in and replacing bearings of centrifugal pumps	2	2	2	2
k. Renewing ram packing on hydraulic steering gears and elevators	2	2	-----	-----
l. Changing seals and gaskets on hydraulic equipment	2	2	-----	-----
m. Inspecting and adjusting food preparation and dishwashing machinery	2	2	-----	-----
n. Inspecting and adjusting safety devices and operating gear on laundry machinery	2	2	-----	-----
o. Dehydrating, testing, and recharging of refrigeration systems	1	-----	2	2
p. Replacing oil seals on refrigeration compressors	1	-----	2	2
4. Methods of testing evaporators and condensers for salt water leaks	2	2	2	2
5. Procedures to be followed when these casualties occur:				
a. Leak in condenser	3	3	-----	-----
b. Deaerating feed tank water level drops during steady steaming	3	3	-----	-----
c. Deaerating tank too full	3	3	-----	-----
d. Gage glass on evaporator breaks	3	3	-----	-----
e. Cooling water to auxiliaries fails	3	3	-----	-----
f. Jammed throttle (ahead and astern)	3	3	-----	-----
g. Lubricating oil cooler tube carries away	2	2	-----	-----
h. Loss of or low lubricating oil pressure	2	2	-----	-----
i. Lubricating oil leak into engine room	2	2	-----	-----
j. Excessive lubricating oil pump discharge pressure	2	2	-----	-----
k. Hot bearings and treatment of overheated bearings	2	2	-----	-----
l. Empty feed bottom in use for make-up feed	2	2	-----	-----
m. Casualty to the deaerating feed tank (DFT)	2	2	-----	-----

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
202 MAINTENANCE AND/OR REPAIR—Continued				
n. Unusual noise from pump end of main feed pump when starting	2	2	----	----
o. Low or loss of main feed booster pump pressure	2	2	----	----
p. Rupture in fuel-oil suction and transfer piping	2	2	----	----
q. Rupture in fire main piping (engineering spaces)	2	2	----	----
r. Rupture in salt water cooling service piping	2	2	----	----
s. Steering gear and propeller casualty—near miss	2	2	----	----
t. Loss of vacuum	1	1	----	----
u. High oil level in the reduction gear case—oil emulsion	1	1	----	----
v. Locking and unlocking of shaft underway	1	1	----	----
w. Shaft vibrates excessively	1	1	----	----
x. Unusual noise in reduction gear	1	1	----	----
y. Metallic noise coming from turbine	1	1	----	----
z. Turbine begins to vibrate	1	1	----	----
aa. Cruising turbine out of commission	1	1	----	----
bb. Rupture in main steam piping (split-plant)	1	1	----	----
cc. Rupture in auxiliary steam piping	1	1	----	----
dd. Rupture in auxiliary exhaust piping	1	1	----	----
ee. Rupture in main feed piping	1	1	----	----
ff. Rupture in high pressure drain piping	1	1	----	----
gg. Rupture in fuel oil heating drain piping	1	1	----	----
hh. Loss of steam pressure in engine room	1	1	----	----
ii. Main turbine casualty—near miss	1	1	----	----
jj. Fire room explosion—torpedo hit	1	1	----	----
kk. Engine room explosion—shell hit	1	1	----	----
ll. Engine room explosion—torpedo hit	1	1	----	----
6. Lubricant requirements, and precautions when handling dehydrated oils for refrigerant systems	1	----	2	2
7. Methods of fitting carbon packing rings to turbines	2	2	----	----

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
202 ADMINISTRATIVE AND/OR REPAIR—Continued				
8. Procedures to be followed when:				
a. Inspecting and reconditioning oxygen, CO_2, and acetylene cylinders	----	----	----	1
b. Checking alinement of couplings and determining clearances of bearings on pumps for gas generating equipment	----	----	----	1
c. Setting relief valves	1	1	1	1
d. Repairing centrifugal pump pressure regulators	1	1	1	1
e. Taking clearances and replacing wearing rings on centrifugal pumps	1	1	1	1
f. Checking alinement of centrifugal-pump driving unit	1	1	----	----
g. Replacing worn and broken reciprocating-pump piston rings	1	1	----	----
h. Adjusting tappets on slide gear of reciprocating pumps	1	1	----	----
i. Adjusting steam reducing valves	1	1	----	----
j. Cleaning first- and second-stage air ejector nozzles and diffusers	C	C	----	----
k. Replacing turbine or reduction gear bearings	1	1	----	----
9. Methods of testing oxygen, CO_2, and acetylene gas generating systems and equipment for proper operation	----	----	----	1
10. Methods of testing refrigerating systems, including compressors, for proper operation	1	----	1	1
11. Factors governing main propulsion plant efficiency, causes of poor performance, and appropriate remedies	C	C	----	----
12. Major causes of inefficient operation of refrigerating systems and corrective procedures	C	----	C	C
13. Procedures for checking and adjusting constant-speed and speed-limiting governors and overspeed trips	C	C	----	----
14. Methods of taking main turbine and reduction gear bearing clearances, thrust clearances, and turbine blade clearances	C	C	----	----

Qualifications for advancement in rating	Applicable rates			
	MM	MML	MMR	MMG
202 MAINTENANCE AND/OR REPAIR—Continued				
15. Procedures to be followed when inspecting propellers, shafts, sea valves, zincs, and strut and stern tube bearings when ship is in drydock	C	C	-----	-----
16. Characteristics of lubricating oil and purpose of tests	C	C	C	C
17. Procedures to be followed when replacing rotors in main feed, main feed booster, main condensate, and main lubricating oil pumps	C	C	-----	-----
18. Procedures for replacing thrust plates in main turbine thrust and turbogenerator thrust bearings and thrust shoes in Kingsbury thrust bearings	C	C	-----	-----
203 ADMINISTRATIVE AND/OR CLERICAL				
1. Duties and responsibilities of the engineer officer of the watch	C	C	C	C
2. Performance reports required by Bureau of Ships and Chief of Naval Operations and purpose of all records kept by engine room personnel	C	C	C	C
3. Selection, procurement, and use of packings, grease, oils, polishes, cleaning materials, spare parts, and other engine room supplies	C	C	C	C
4. Use of allowance lists, and procedures for maintaining inventories and obtaining replacements	C	C	C	C
5. Application of damage control principles	C	C	C	C
6. Knowledge of administrative, material, and operational readiness inspections	C	C	C	C
7. Supervise and make out reports for full power, economy, dock, and post-repair trials	C	C	-----	-----
300 PATH OF ADVANCEMENT TO WARRANT OFFICER AND LIMITED DUTY OFFICER				
Machinist's Mates advance to Warrant Machinist and/or to Limited Duty Officer, Engineering.				

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